IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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COMING MEETINGS

PITTSBURGH SECTION

"MAINTENANCE — STEAM TURBINES"

By A. L. Penniman, Supt. of Steam Stations, Consolidated Gas Electric Light & Power Company of Baltimore. Baltimore, Md.

Saturday, May 1st, 1926.
Dinner—6:30 P. M.
Paper — 8:00 P. M.

Blue Room,
Wm. Penn Hotel,
Pittsburgh, Pa.

PHILADELPHIA SECTION

SATURDAY, APRIL 10th, 1926.

"GENERAL IDEAS AND DISCUSSION"

Every active member is invited to prepare a short paper on a subject pertaining to the application of electricity to the Iron and Steel Industry.

MAY—1926.

INSPECTION TRIP

The Bethlehem Steel Company invites the members of the Association to visit the Maryland Plant of the Bethlehem Steel Company located at Sparrows Point, Maryland. Details will be announced later.

All meetings of the Philadelphia Section are held in the Engineers Club, 1317 Spruce Street, and will start promptly at 7:30 P. M. They are preceded by an informal dinner at 6:00 P. M.

TWENTY-SECOND ANNUAL CONVENTION

Hotel Sherman, Chicago, Ill. June 7th to 10th, inclusive.

MONDAY, JUNE 7th, 1926.

SAFETY CONGRESS

A. I. & S. E. E. Recommendations "Rules for the Safe Operation of Electric Overhead Traveling Cranes".

TUESDAY, JUNE 8th, 1926.

Standardization of Mill Type Motors—
Addition to Rolling Mills at Steubenville Plant of Wheeling Steel Corporation—By M. J. Conway.

WEDNESDAY, JUNE 9th, 1926.

Refractories for the Iron and Steel Industry—By M. S. Booze, Senior Fellow Mellon Institute, Pittsburgh, Pa.
Open Hearth Roof Construction—By W. J. Harper.
Coke Ovens—By M. J. Conway.
Boilers—By F. G. Cutler.
Heating Furnaces—By E. W. Trexler.
Chrome Brick—By A. J. Steed.
Blast Furnace Linings, Open Hearth Furnaces, Heating Furnaces } By W. H. Kelly.

Report of Electric Heat Committee.

THURSDAY, JUNE 10th, 1926.

"ELECTRIC TRANSPORTATION, YARDS, MILLS, SHOPS AND FACTORIES."

—By—

Harold J. Payne, Representing The Society for Electrical Developments.
W. B. Potter, Engineer Railway Department, General Electric Company.
O. H. Needham, Engineering Dept. Westinghouse Electric & Manufacturing Company.
J. C. Thirlwall, Railway Engineering Department, General Electric Company.

FRIDAY, JUNE 11th, 1926.

INSPECTION TRIP

CLEVELAND DISTRICT SECTION

Saturday, April 24th, 2:30 P. M. Electric Legue Rooms, Statler Hotel, Cleveland, O.

SAFETY CONGRESS

"Rules for the Safe Operation of Electric Overhead Traveling Cranes".

Tech. 50

EDITORIALS

ELECTRIC HEATING

Almost every technical periodical which is serving the Steel Industry contains an article in connection with Electric Heat. It seems that everyone has awakened to the fact that this form of heating has possibilities in the Iron and Steel Industry.

As a word of warning to the Electrical Manufacturers and to the Electric Furnace Builders, propaganda and sales talks not alone will convince the Steel Industry that this form of heating is preferable to those types of heating they are now using. The Electrical Manufacturers and the Electric Furnace Builders must, if they expect to succeed and receive serious consideration, submit actual operating data to the engineers and executives of the Iron and Steel Industry.

The Association of Iron and Steel Electrical Engineers is willing to co-operate with the Electrical Manufacturers and Electric Furnace Builders provided, however, that the Association is furnished with the actual operating performances of the Electric Heating applications which are now in use in this country. A questionnaire has been submitted to all of the manufacturers of electrical equipment, and to the Electric Furnace Builders. So far, the results obtained from this questionnaire have not been satisfactory. Many of the manufacturers have answered this questionnaire with catalogues, pictures, sales talk and propaganda of various sorts. This is not what the Steel Industry desires. They want the facts.

SAFETY CONGRESS

About three hundred and fifty Safety Directors and Electrical Engineers attended the Safety Congress, held March 12th, at the Wm. Penn Hotel, Pittsburgh, Pa. This meeting was one of the most enthusiastic gatherings ever held under the auspices of the Association of Iron and Steel Electrical Engineers.

The Safety Division, headed by Mr. C. L. Baker, Management's Representative, Bethlehem Steel Company, Johnstown, Pa., certainly provided a program for the consumption of the Safety Engineers of the Steel Industry which was thoroughly enjoyed by everyone present.

The attendance represented every Steel district in the United States and the discussions which were presented indicated how thoroughly organized the Steel Industry in general is in standard practices to eliminate the hazards in connection with the operation of Electric Overhead Traveling Cranes.

The Committee in charge of the Safety Congress were:

C. L. Baker, General Chairman; Managements Representative, Bethlehem Steel Company, Johnstown, Pa.

R. G. Adair, Vice Chairman; Safety Director American Rolling Mills Co., Middletown, Ohio.

J. A. Oartel, Safety Director, Carnegie Steel Company, Pittsburgh, Pa.

A. C. Germain, Safety Director, Minnesota Steel Company, Duluth, Minnesota.

W. S. Hall, Electrical Engineer, Illinois Steel Company, So. Chicago, Ill.

J. C. Reed, Electrical Engineer, Bethlehem Steel Company, Steelton, Pa.

A. C. Gibson, Safety Director, Spang-Chalfant Company, Etna, Pa.

Walter Greenwood, Safety Director, Carnegie Steel Company, Youngstown, Ohio.

RULES FOR THE SAFE OPERATION OF ELECTRIC OVERHEAD TRAVELING CRANES

In answer to the circular letter which was forwarded to all of the Steel Plants in the United States, requesting a copy of the Rules which govern the Operation of Electric Overhead Traveling Cranes, about one hundred Steel Companies have submitted their rules.

The Safety Division together with the Electrical Division of the Association of Iron and Steel Electrical Engineers will propose at the Twenty-Second Annual Convention to be held at Chicago, a set of recommendations covering "Practical Crane Operators' Rules."

It is hoped that the Association, with the assistance of the Steel Companies who have so generously contributed their Rules that they are now using, will be able to formulate a set of recommendations which will be applicable to the Steel Industry as a whole.

The minutes of the Safety Congress held in Pittsburgh, and which will appear in the May Issue of the Iron and Steel Engineer, clearly indicate that such a set of rules will be of enormous value to the Steel Industry. These rules will at least indicate what is good sound practice.

STANDARDIZED MILL TYPE MOTOR

The Standardization Committee of the Association of Iron and Steel Electrical Engineers met in Cleveland, on March 12, to discuss with the manufacturers the problems involved in developing a standard mill type motor for steel mill service.

Representatives of the General Electric Company, Westinghouse Electric and Manufacturing Company, Reliance Electric and Engineering Company, Crocker Wheeler Company and the Electro Dynamo Company were present.

The Standardized Committee submitted to the manufacturers comparisons of the external dimensions of the present line of mill type motors, indicating that the differences existing in present designs were so slight as to lead them to believe the problem of selecting the standardized dimensions for future designs was not a difficult one to solve.

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Methods of Acceleration of Direct Current Mill Auxiliary Motors

By C. J. SMITH*

THERE have been developed recently a number of new types of magnetic controllers for direct current mill auxiliary motors which have focused considerable attention on the question of the relative merits of current limit and time limit acceleration. It is the purpose of this paper, which has been prepared in collaboration with the various manufacturers, to present for your consideration and discussion, the fundamental principles, and the characteristics and limitations of these different schemes.

Some of these equipments are of relatively recent origin and have not been widely adopted. If considerable emphasis is placed on any particular type of control, in the following discussion, it is not to be construed as an unqualified approval of the apparatus, but a measure of the interest naturally exhibited in something new for the advancement of the art of motor control.

The following discussion is limited to a consideration of the methods of automatic acceleration of

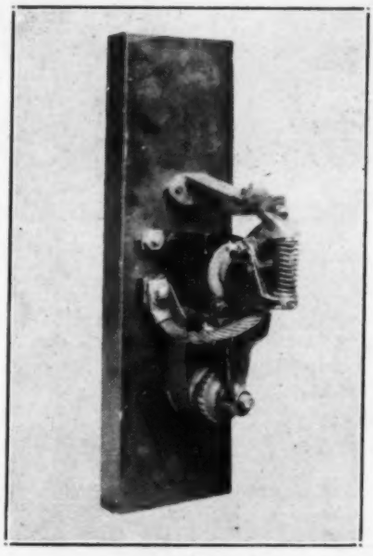


FIG. 1

direct current motors, no comparisons being drawn between contactors, resistors, protective devices and master switches which are necessarily a part of a magnetic controller.

Current limit controllers are satisfactory where load conditions are fairly constant. It is necessary to adjust a current limit controller for the most severe load condition. In the steel mill this means that a current limit controller on a table motor must have its relays adjusted to allow the motor to accelerate its load, when starting up with the table cold and stiff. Due to operation in the presence of hot steel the table soon limbers up and operates freely. The torque requirements are greatly reduced as far as successful acceleration is concerned. However, the series relay setting allows the motor to take the same severe peaks, resulting in faster acceleration, at the expense of the motor.

In the same way a current limit hoist controller must be adjusted to accelerate a load corresponding to the maximum capacity of the hoist, although the maximum load condition may be encountered only at long intervals.

With time limit acceleration on the drives just described it is evident that the motor will successfully accelerate its load, the resistance being cut out of circuit in definitely timed steps. The motor input will vary with load conditions, up to the value determined by the setting of the protective devices,

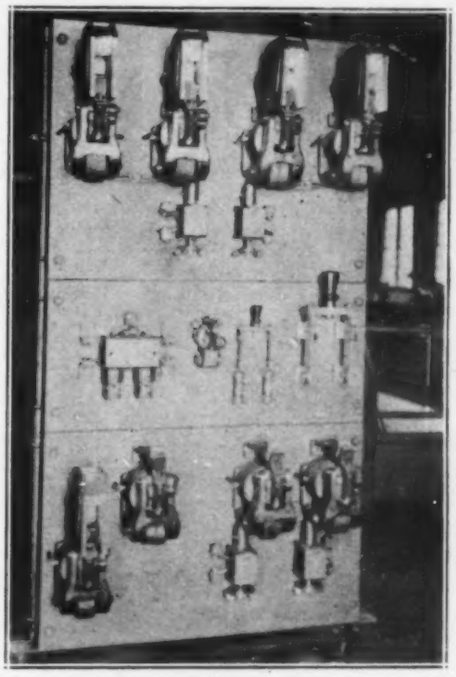


FIG. 2.

provided that much power is required for acceleration. Positive acceleration is, therefore, assured apparently at the expense of motor protection.

However, if it can be assumed that maximum load conditions obtain a very small percentage of the time, it is possible to reach the conclusion that the motor is subjected to less abuse with time limit control, where the input corresponds to load and operating requirements, than with current limit equipment where the motor input is always at a maximum, regardless of operating requirements

On loads of widely variable enertia, time limit acceleration would have a tendency to unduly force the acceleration of the motor by cutting out the starting resistor too quickly when the high inertia

Presented at Chicago, January 27, 1926.

*Asst. Elec. Engr., Illinois Steel Co., So. Chicago, Ill.

load was encountered. Some compromise would, therefore, have to be made between the fastest possible acceleration of the average load, and the ability to successfully accelerate the maximum load.

In steel mill operation where continuity of operation is paramount certain refinements of control may be sacrificed to obtain the maximum of simplicity. Therefore equipment of simple design, with few parts and simple circuits and a minimum of relays and contacts, must be looked upon with favor.

Magnetic controllers may be grouped under the two general headings of current limit and time limit acceleration, depending on the methods used to short circuit the starting resistor. Under the heading of current limit, the following types would be classified: —counter e.m.f.—series lockout—series relay—and voltage drop.

The counter e.m.f. or counter voltage scheme controls the cutting out of the starting resistor by

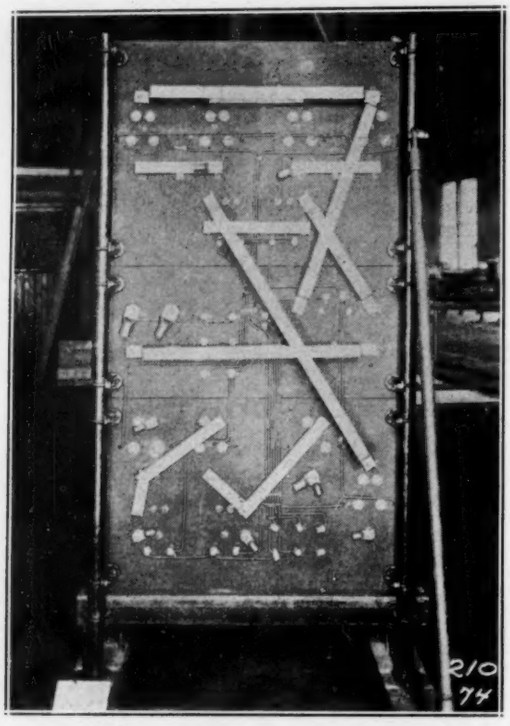


FIG. 3.

employing the voltage generated as the motor armature accelerates. The accelerating contactor closing coils are connected across the armature, or the armature and a part of the resistor, and the coils and air gaps adjusted to give the proper sequence of operation. Another scheme involves the use of one closing coil and a suitable number of contact arms, with air gaps graduated to close the arms in sequence as the armature accelerates, building up counter voltage and increasing the excitation on the closing coil.

The series lockout scheme of control employs accelerating contactors equipped with closing coils wound with heavy copper connected in series with the load current. There are two general types of contactors under this heading.

The single coil lockout contactor consists of a series coil furnishing excitation for the production of magnetic flux in the iron frame of the contactor. The iron is arranged to provide two paths in multiple for the flux. The flux tending to close the contactor follows a path of restricted area, which becomes saturated due to high values of starting current, forcing a certain amount of flux through the

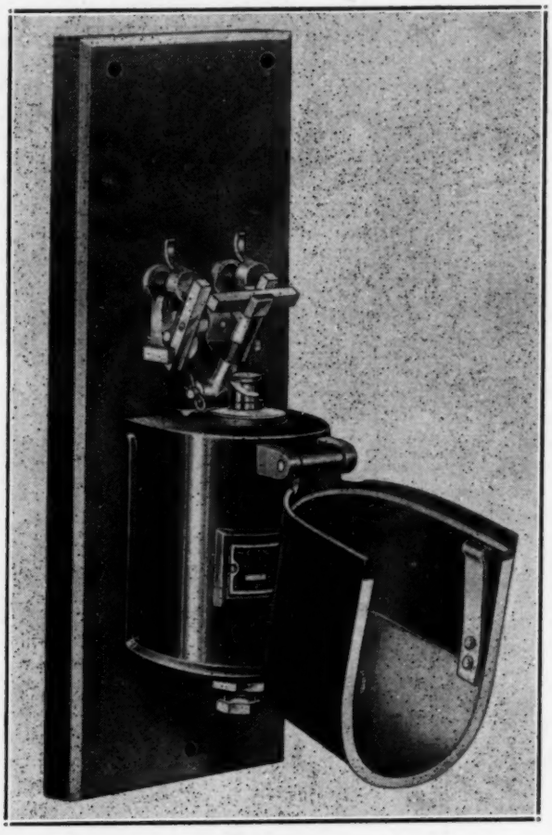
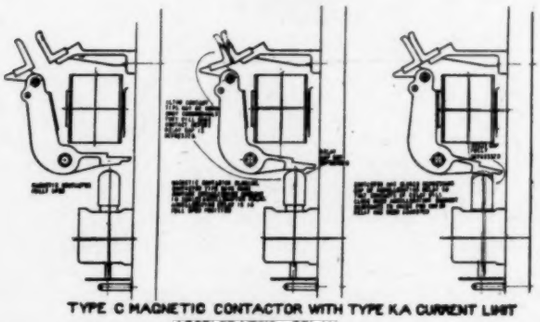


FIG. 4.

second or lockout path. As the motor starting current decreases the lockout flux becomes less and the contactor closes, short circuiting one step of the starting resistor.

The path of the closing flux being restricted the pull in flux is limited. The holding flux varies with



TYPE C MAGNETIC CONTACTOR WITH TYPE KA CURRENT LIMIT ACCELERATING RELAY

FIG. 5.

the motor current and results in variable contact pressure on power contacts, falling to such a low value at light loads that the accelerating contactors may drop open. If the drive is over motored and series lockout switches provided of a size correspond-

ing to the motor, the last accelerating contactors may not close at all.

Another type of series lockout switch, Fig. 1, is provided with two series coils, one a closing coil and one a lockout coil. In this case the path of the closing flux is not restricted. The lockout coil is so connected that the closing of the contactor short circuits the lockout coil. This arrangement gives stronger closing and holding flux, but is subject to

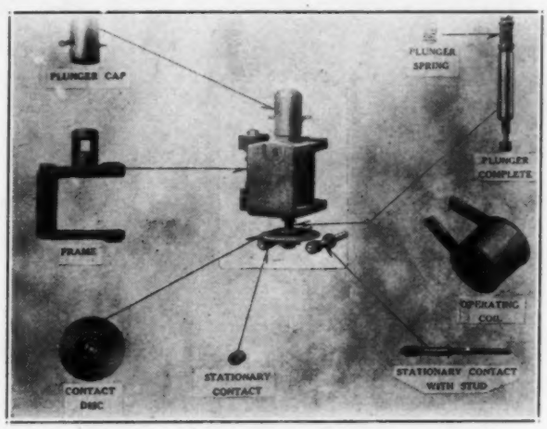


FIG. 6.

the same disadvantages as described under the single coil type.

The series lockout scheme of control eliminates relays and auxiliary contacts. Unusually heavy load conditions will cause the resistance to remain in the circuit. A variety of sizes of series switches is required, as the series coil must correspond to the capacity of the motor with which it is to be used.

The series relay type of control, Fig. 2, employs shunt coils on all contactors. Series relays, with

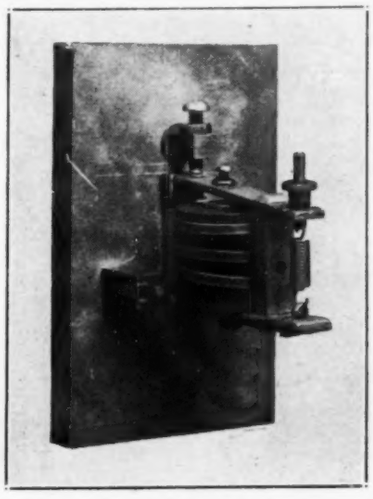


FIG. 7

auxiliary contacts are employed to control the closing of the plugging and accelerating contactors. The relays may be mechanically connected to the contactors or not depending on the methods used to operate the relays.

One manufacturer employs a normally open series relay, which operates on a magnetic lockout principle and remains open until the motor current decreases to a predetermined adjustable point. At this point the lockout flux has been weakened, which allows the relay to close its contacts. This completes the closing coil circuit on the accelerating contactor and the contactor closes. This process is repeated then for each accelerator.

Another method employs a relay whose contacts are held normally open by the action of a coil spring

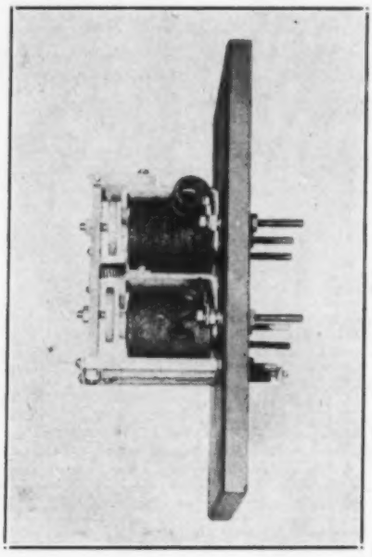


FIG. 8.

used to lift the relay armature. As the directional contactors close a power circuit is established at the instant the tips touch. This excites the series relay so that by the time the contactor has completely closed, thereby removing the mechanical lift of the coil spring, the relay armature is held up by the flux due to the motor starting current. As the motor accelerates and the current decreases the relay armature drops, closing the circuit on its contacts and allowing the next accelerator to close. This is repeated for each accelerating relay.

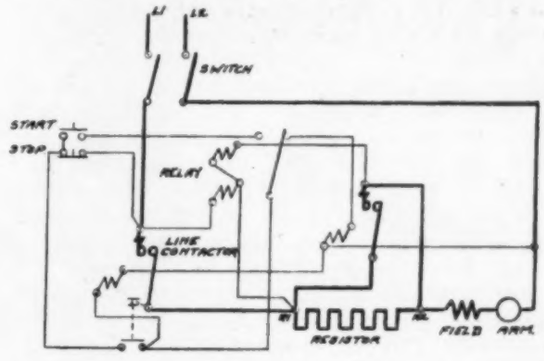


FIG. 9.

A third manufacturer employs a relay whose armature is lifted mechanically by the opening of its corresponding contactor. As the directional contactor starts to close, a power circuit is established through the contactor tips, establishing a current which excites the series relay coil, producing a flux which will maintain the relay armature in the raised

position, when the mechanical lift is removed, providing the motor current is in excess of the calibrated setting of the relay. This scheme is quite similar to the one just previously described.

Still another type of series relay consists of a series coil with contacts normally closed by spring pressure. The closing coil circuits of the accelerating contactors pass through the contacts of the series relay and an auxiliary contact on the proper contactor. As the contactor starts to close a power circuit is established through the contacts, exciting the series relay coil. The series relay contacts are then pulled open before the contactor auxiliary contacts are made, thus preventing the closing of additional

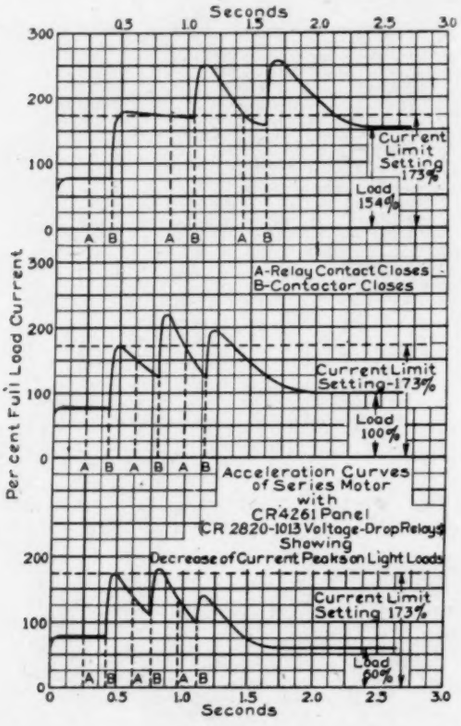


FIG. 10.

accelerators until the starting current has decreased, allowing the relay contacts to again close, due to spring pressure.

The voltage drop system of control employs relays operated by shunt coils excited by the voltage drop across sections of the starting resistor. This voltage drop is proportional to current and the control is therefore essentially a current limit control.

The voltage drop relay is equipped with two duplicate shunt wound coils capable of standing line voltage. Its contacts are normally closed. When the line switch is closed, a circuit is completed on the lower or assisting, relay coils, and all of the relay armatures pick up, opening their contacts. When the directional contactors close the assisting coil on the first accelerating relay is short circuited. This leaves the relay armature held up by the calibrated coil, excited by the voltage drop in the resistor. As the motor accelerates this voltage drop decreases and a point is reached where the relay contacts close, completing the closing coil circuit for the succeeding accelerating switch. This process is repeated until all of the resistance is cut out of the motor circuit.

The voltage drop scheme of control is described very completely in an article entitled, "Control Equipments for Auxiliary Motors," published in the 1921 proceedings of the Association of Iron and Steel Electrical Engineers. Reference should be

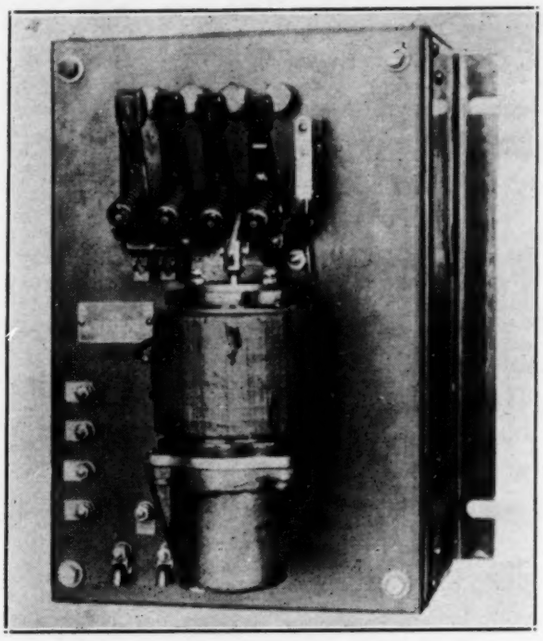


FIG. 11.

made to this publication for a complete digest of this scheme of control.

The voltage drop control success fully eliminates series coils from the accelerating scheme and provides an equipment suitable for use with any size motor within the range of the contactor ratings.

It is claimed that this control has certain advantages over other types of current limit controls as follows: When the assisting coil is short circuited, there is a time lag in the decay of flux in this iron

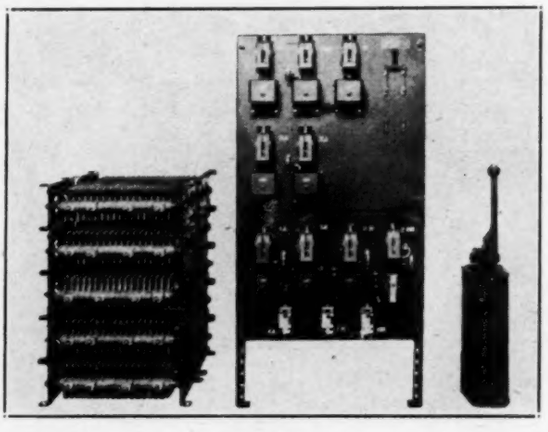


FIG. 12.

circuit due to the self induction of the short circuited coil. If the motor is operating at light load and the IR drop impressed on the relay calibrated coil is below the hold in value, it is evident that the inductive lag determines the time of releasing the relay armature. Due to this characteristic it is possible to calibrate the relays for a high motor input to meet heavy load conditions, and yet on light loads

relieve the motor somewhat of this high input when not required by operating conditions.

Under time limit controls may be mentioned those types which function through the operation of an

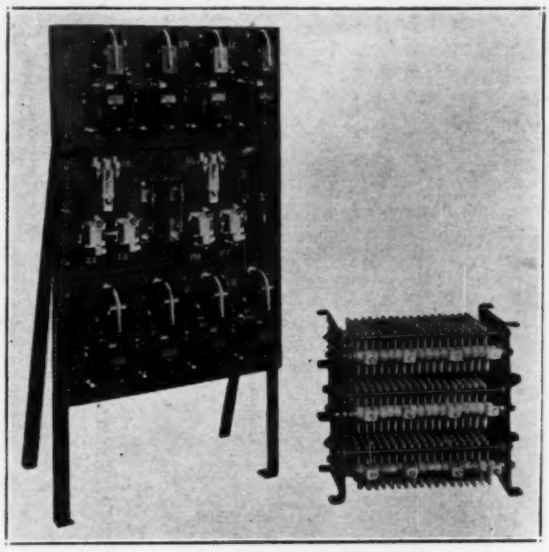


FIG. 13.

auxiliary motor or a solenoid, but which are not considered pertinent to this discussion.

The use of oil or air dash pots to obtain time limit acceleration, carries with it many disadvan-

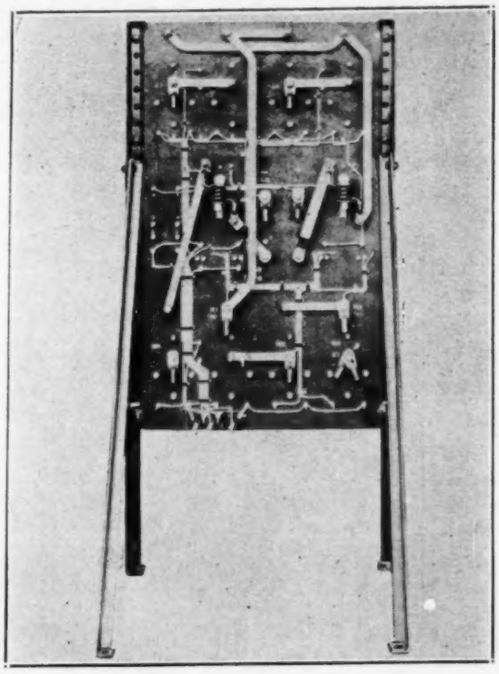


FIG. 14.

tages due to the difficulty of maintaining adjustments on needle valves and to the changing viscosity of oil when subjected to wide variations in temperature. However, there are many satisfactory installations of this type, their success being due to favorable atmospheric and temperature conditions.

A recent development in time limit acceleration, which is of interest is the type MT equipment developed by the General Electric Company.

This equipment employs shunt relays which function to time the closing of the resistor contactors. These relays are constructed to have a time lag due

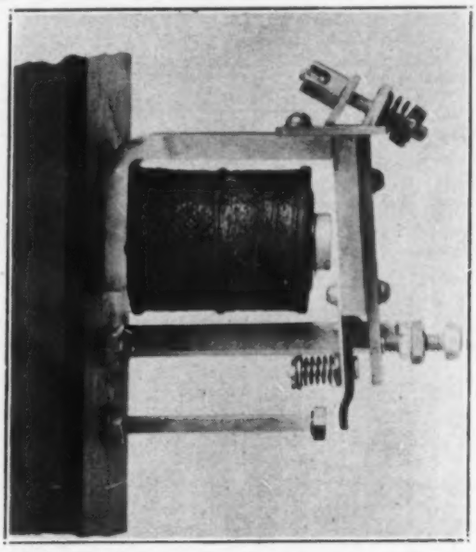


FIG. 15.

to self induction of a short circuited coil. This lag produces the time delay between the closing of the consecutive resistor contactors and is adjustable by means of adjustments of a tension spring working against a magnetic pull on the relay armature and by means of varying the thickness of a non-magnetic

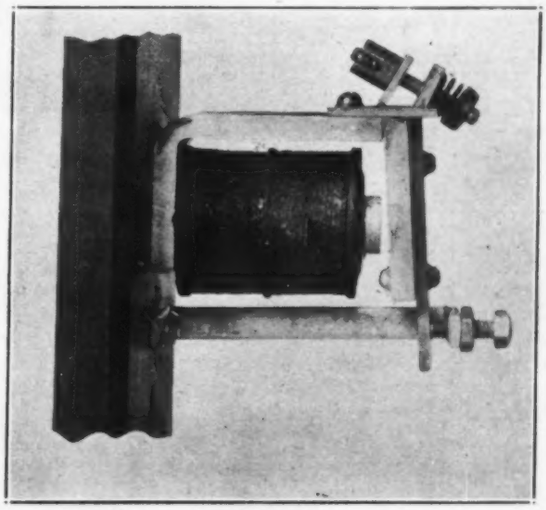


FIG. 16

shim used to introduce a magnetic gap between the core and the relay armature.

The control of the plugging contactor is effected by the use of a forward and a reverse plugging relay of the current limit type. The shunt coil of the plugging relay is connected across the armature and the plugging resistor, its circuit being completed by auxiliary contacts carried by the directional contactors.

In starting from rest a voltage drop is impressed on the plugging relay coil due to the flow of current through the plugging resistor. The relay armature

then picks up, closing the normally open plugging relay contacts. This completes the closing coil circuit on the plugging contactor, which closes very quickly following the directional contactors.

In plugging, the counter voltage of the motor opposes the IR drop in the plugging resistor, resulting in very low voltage on the plugging relay coil. As the motor decelerates the counter voltage decreases and the IR drop across the plugging resistor becomes effective in exciting the plugging relay shunt coil. The actual time of closing the plugging relay and contactor can be varied to suit, but would usually occur at approximately zero speed.

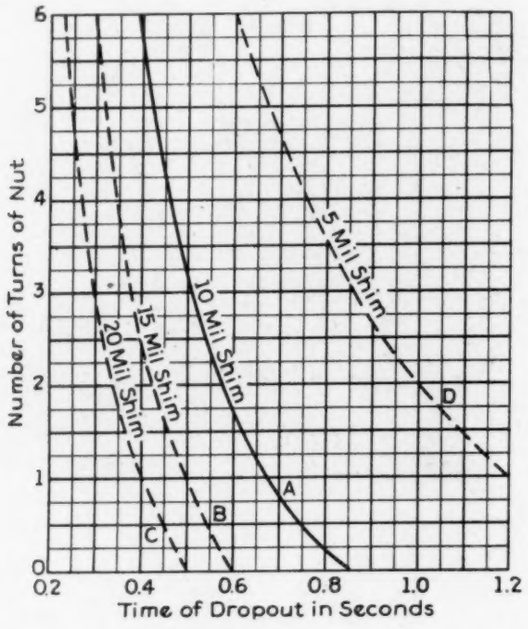


FIG. 17

The accelerating relays are duplicate of the plugging relays except the contacts are normally closed. These relays function as time limit relays as previously described. When the reversing contactors establish a power circuit through the motor and the starting resistor, a voltage drop is impressed on each accelerating relay coil, since they are connected across the individual resistor steps. This impressed voltage drop causes the relay armatures to pick up, opening the normally closed contacts, before the common closing wire circuit is completed through the plugging relay contact.

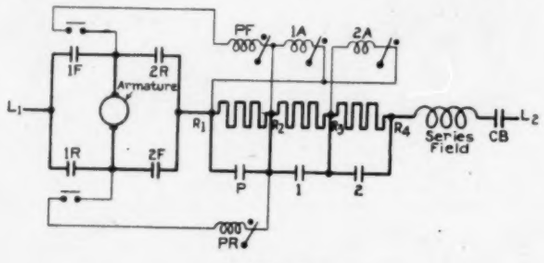


FIG. 18

The accelerating relay timing is capable of adjustment by means of the spring tension and non-magnetic shim as described under plugging relays.

The wiring diagram shows the connections for the relay coils. The plugging relays are connected across the armature and plugging resistor, with a mechanically operated contact in the relay coil circuit, closed by the operation of the proper directional contactor. The accelerating relay coils are connected across steps of the resistor. The first accelerating relay coil is connected across the plugging resistor. When the plugging contactor closes, the first accelerating relay coil is short circuited, and will close its contacts after a definite time required for the decay of the flux holding the armature closed.

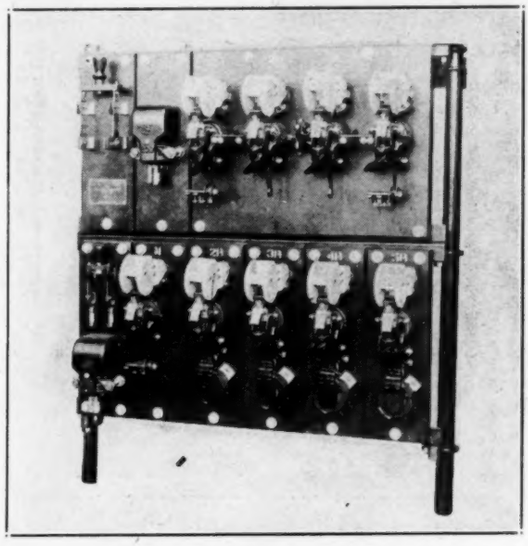


FIG. 19

Another development of time limit control is the Cutler Hammer inductive time limit system. The timing employed on this system is produced magnetically through the medium of a transformer. The accelerating contactors are equipped with a shunt closing coil and a second shunt lockout coil.

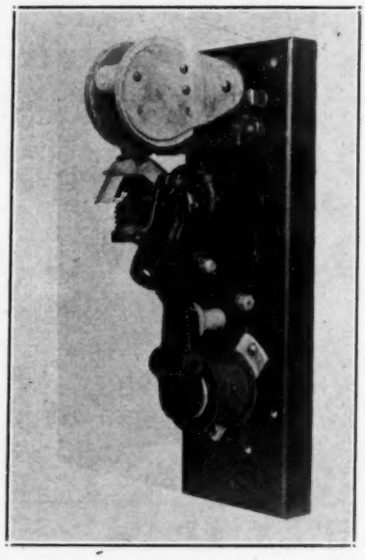


FIG. 20

The shunt lockout coil derives its excitation from a transformer. This transformer consists of an iron

core equipped with a primary coil and a secondary coil for each of the plugging and accelerating contactors. During the accelerating period the motor current is changing rapidly and a resulting flux is developed in the transformer iron dependent on the rate of change of current in the motor, the resulting voltage drop applied to the primary transformer coil, and the corresponding rate of change of current in the primary coil.

The transformer is mounted on the rear of the panel with a duplicate shunt coil for the primary, plugging and accelerating contactors assembled on a common iron core.

The diagram shows the connections of the transformer and lockout coils. It will be noted that the polarity of alternate secondary coils is reversed. This scheme of connections assures a complete reversal of flux each time an accelerator closes and gives the required delay in timing the accelerators.

In starting from rest excitation on the primary coil is due to the IR drop in the plugging resistor,

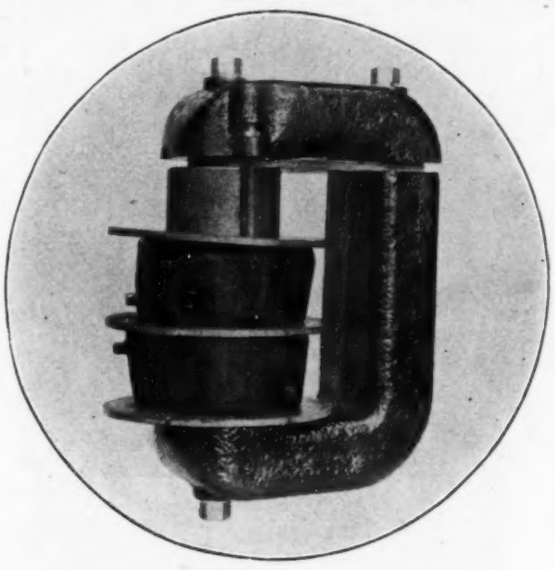


FIG. 21

since the armature is at rest. There is little induced power in the lockout coil and the plugging contactor closes quickly following the directional contactors.

It will also be noted from the diagram that as soon as a power circuit is established, a voltage drop is impressed across each lockout coil in series with its corresponding transformer secondary coil. It is the resulting excitation from this voltage drop which prevents all of the accelerators from jumping at the time of closing of the plugging contactor.

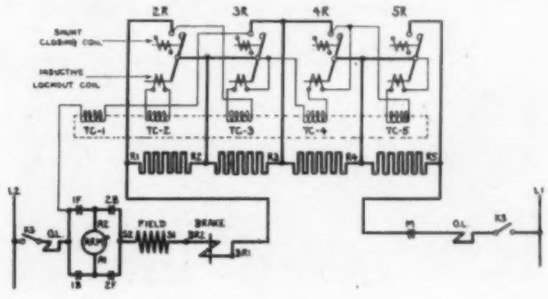
In plugging there is a rapid change of excitation on the primary coil due to the rapid decrease in armature counter voltage and a strong locking-out effect is exerted on the plugging contactor. When the plugging contactor closes, the lockout coil of the first accelerator and the transformer secondary coil are connected in a closed circuit. At this time there is a resultant flux in the transformer core due to the excitation of the primary coil, the voltage drop excitation of the remaining accelerating lockout and transformer coil circuits and the short circuited plugging contactor coils.

When the first accelerator closes, there is a change in the excitation on the primary coil, and an additional pair of coils have their voltage drop excitation removed and are closed upon themselves. The result is a change of polarity in the resultant total transformer flux. The time required to destroy the existing flux and build up the flux to a maximum in the opposite direction represents the time de-

FIG. 22

lay before the closing of the next accelerator. This reversal of flux obtains for the control of each accelerator until the starting resistor is completely cut out.

This control has practically eliminated secondary contacts in the control of accelerating contactors and uses no series coils. The time delay is adjustable by means of an adjusting screw regulating the magnetic gap in the accelerator lockout path.



CUTLER-HAMMER INDUCTIVE TIME LIMIT CONTROL
BRIDGE & TROLLEY- REVERSING CONTROLLERS.

FIG. 23

An additional advantage is claimed for this control of having certain current limiting features as follows: If the motor is accelerating its load rapidly, it is evident that the motor current is changing rapidly and a longer time is required to lose the effect of induced flux, due to the changing motor current. In this way, during light load conditions, the acceleration of the motor is not forced as would be expected on straight time limit control.

*Lightning Arrester Protection on 13,200 V. and 2,400 V. Distribution Lines**

By A. R. WOOD†

THE Central Station man in considering lightning arrester protection on distribution lines has at least two questions to answer:

(1) Where should arresters be installed?

(2) How effective are arresters in reducing lightning trouble?

The following discussion gives a partial answer to those questions based on the practice and experience of the Philadelphia Electric Company:

Protection Problem

In the first place, the Central Station Company is confronted with the necessity of maintaining continuous service to its customers. In the second, it is highly desirable to minimize damage to electrical equipment. On our own system, when a 2400 V. lighting transformer fuse is blown in a lightning storm, from fifty to three hundred customers are without service until a trouble man, of whom there are twelve located in various sections of the City, can be notified by the Trouble Dispatcher of the failure, and can replace the fuse.

In case a transformer lead or terminal board is damaged, a longer outage occurs while the trouble man is making temporary repairs. Of course, if the transformer is damaged beyond immediate repair,

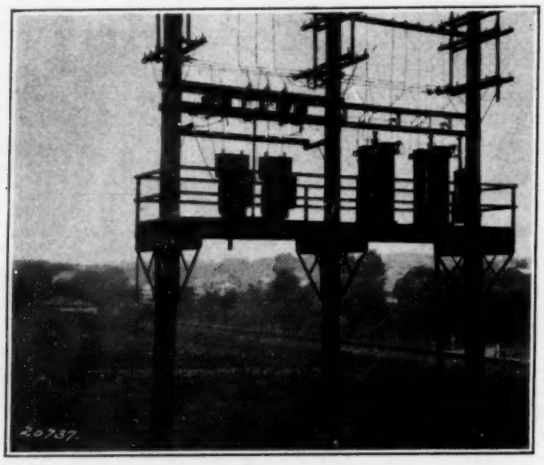


FIG. 1.

the trouble man must either cut the load to an adjacent transformer, or make arrangements for having a portable emergency substation connected to the secondaries involved. On the average, cases of outside trouble are handled in forty-five minutes.

The above gives some idea of the seriousness of lightning trouble on distribution systems. Any one of the three kinds of trouble may develop from the same lightning disturbance, the difference merely being in the amount of damage done. This sort of failure, while unavoidable in some cases, should be kept at a minimum, not only on account of the interruption involved, but because straightening out this trouble puts a load on the Trouble Department, in addition to that which necessarily follows any storm, whether or not attended by lightning. The same considerations apply to 13,200 V. transformer installations, but are more serious, owing to the greater capacity of the equipment involved.

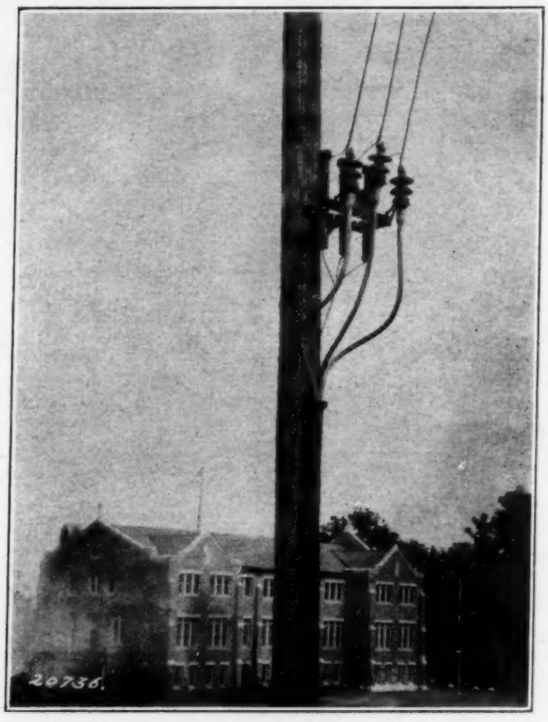


FIG. 2

In addition, the Central Station Company requires protection at terminal poles, that is, the junction points between aerial lines and underground cables. In most cases the cable is comparatively short, joining the overhead line either to a company or to a customer's substation. This is done to protect both the cable and the switching and transforming equipment. The protection of substation equipment was formerly accomplished by means of indoor arresters, largely of the electrolytic type. In accordance with modern practice to cut down fire hazards and to release substation space, we are changing over to pole-top arresters for 13,200 V. terminal poles and also for 2400 V. terminal poles where our experience has indicated that they are necessary. The protection which we require then is at the following points:

(1) On practically all 13,200 V. transformer installations.

(2) On a large number of 2400 V. transformers

(3) On all substation and customer 13,200 V. terminal poles.

*Presented at Philadelphia, November 7, 1925.

†The Philadelphia Electric Co., Philadelphia, Pa.

(4) On certain selected 2400 V. substation terminal poles.

Figures 1 to 5 illustrate the methods of mounting 13,200 volt arresters. A typical 400 KVA regulated equipment with arresters mounted on the transformer cases is shown in Figure 1. This particular equipment steps down from 13,200 volts to 2400 volts for lighting service in outlying territory. Figure 2 shows 13,200 volt arresters mounted on the bracket holding the cable terminals.

Figures 3 and 4 illustrate the mounting of two types of 2400 volt arresters on transformer poles, the taps to the arresters are made to the 2400 volt line alongside the transformer taps to the line. Figure 5 gives a good example of the mounting of 2400 volt arresters on a two circuit terminal pole.

There were until recently two theories of lightning arrester protection. The first involved the location of the arresters along the lines to drain off over voltages as they were induced, thus protecting all equipment including line insulators. The second theory calls for location of the arresters immediately

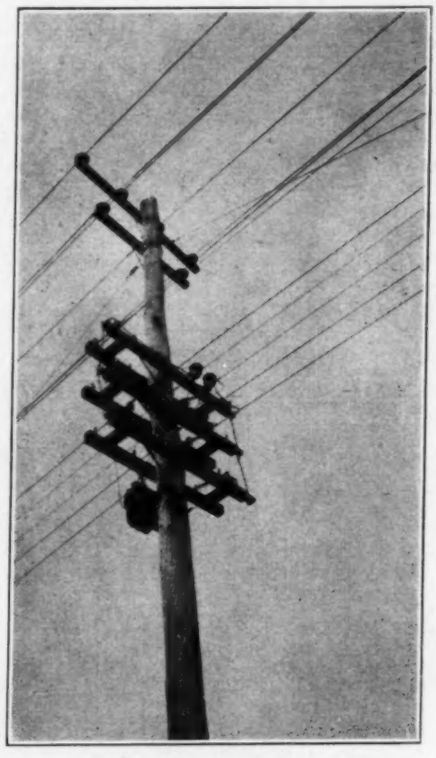


FIG. 3.

at the particular equipment which it is desired to protect. The second theory is now generally held to be correct.

For several years we have been experimenting with 13,200 volt arresters along the lines. These arresters have, in a number of cases, functioned, and undoubtedly have relieved the lines in their immediate locality of excessive voltages, but they have not protected equipment located short distances away. Arresters located between two transformer installations do not give partial protection to both, as might be expected; whereas, arresters installed on one transformer installation do protect that installation to a very large degree.

A study of the lightning trouble experienced in a territory for which partial protection had been provided leads to the same conclusion in connection with the protection of 2400 V. transformers. The protected transformers were very seldom hit, but the unprotected transformers were hit at approximately the same frequency as all of the transformers before any protection was installed.

2400 Volt Operating Results

During 1924 and 1925, we followed very closely the distribution of lighting trouble on 2400 V. transfomers in Philadelphia. In 1920 and 1921, before any of the modern type of lightning arresters were

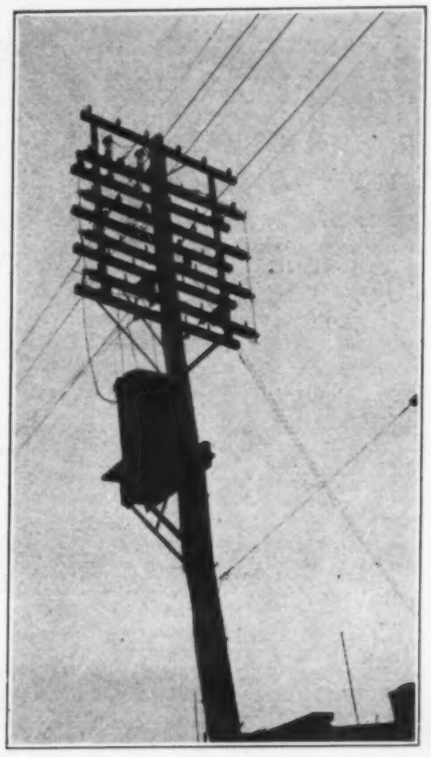


FIG. 4.

installed on these transformers, the northern section of the City from Manayunk and Chestnut Hill over to Tacony was suffered most severely from lightning disturbances. During the period 1922-23 lightning arresters were installed quite extensively throughout this whole region.

The map of the 1924 trouble (Figure 6) shows to some extent the results of installing this protection; each case of trouble is worked by a white spot. There is, however, an area to which we shall refer as the Hunting Park-Ontario area, lightly outlined on Figures 6 and 7, which appears to be more subject to lightning disturbances than the balance of the city. The fuse and transformer failures, due to lightning during the early part of 1925, indicated the same general relationship between this territory and the rest of the city. For this reason we installed lightning arresters on approximately 65 per cent of all transformers in this territory, choosing transformers of 25 KVA and over for this protection on account of the larger number of connected customers and also on account of the value of the equipment

protected. Figure 7 shows the 1925 lightning trouble.

The following tabulation of lightning trouble on 2400 V. transformers, gives an indication of what was accomplished by this protection. The approximate date of installation of the arresters in the area was June 20. For this reason trouble before and after this date have been separated:

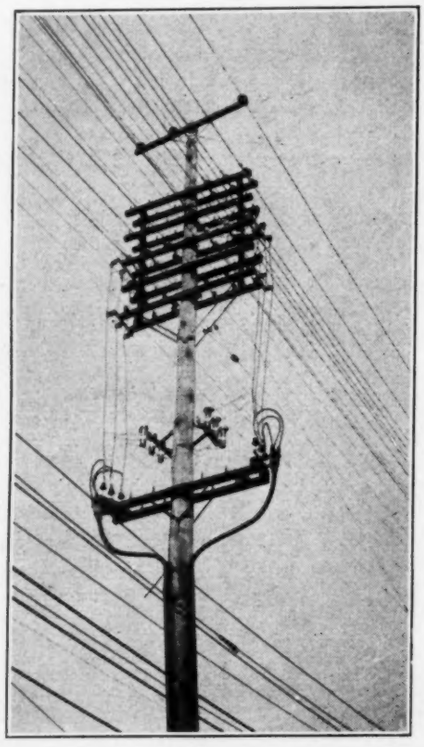


FIG. 5.

Lightning Trouble on 2400 Volt Transformers
Fuse Failures and Transformer Damage

	1925			1924
	Before June 20	After June 20	Total	Total
H.P.-Ontario Area	17	13	30	57
System	75	132	207	166
Ratio $\frac{\text{H.P.-Ont.}}{\text{System}}$	23%	10%	15%	34%

Cases of Trouble per 100 Transformers

	System	H.P.-Ontario
1924	2.4	10.6
1925	3.0	5.6 (3.6)

In 1924 the amount of trouble in the Hunting Park-Ontario area was 34 per cent of the total trouble on the system. During 1925 the amount of trouble before the protection was 23 per cent of that of the system. After the partial protection of the Hunting Park-Ontario area the percentage was reduced to 10.

An analysis of trouble according to the number of cases per 100 transformers gives another way of showing the degree of protection afforded by these arresters. In 1925 the number of cases of trouble per 100 transformers for the system was 3.0, while during 1924 it was 2.4; an increase of 25 per cent for 1925 over 1924. Since protection conditions for the system were the same during both years, with the exception of the small area under special consideration, it is reasonable to believe that lightning disturbances were more severe during 1925 than during 1924.

In spite of this fact, the introduction of partial protection in the Hunting Park-Ontario area on June 20, 1925, cut the amount of trouble per 100 transformers from 10.6 in 1924 to 5.6 in 1925. We estimate that if the same degree of protection had been provided for the whole of 1925, the trouble would have been reduced to one-third of that in 1924, as indicated by the figures in the brackets (3.6).

The apparent protection which this type of arrester has given may be expressed in still a different way by saying that the number of strikes on a given number of protected transformers was one-ninth of the number of strikes on the same number of unprotected transformers.

In following 2400 V. transformer trouble, we have found the use of a card record (Figure 8) extremely

FIG. 6.

valuable. Our reason for saying this is that in some cases we have discovered conditions which contributed to the failure, such as high terminal boards of the type put out by both the General Electric Company and the Westinghouse Electric and Manufacturing Company previous to 1910, also defective bushings and low oil level. Such conditions are remedied as a matter of routine when a transformer

is removed from the line by being brought into the repair room and given a general overhauling. At this time, it is our practice to remove high terminal boards, refill bushings and replace oil.

A record of the sort shown in Figure 8 gives in addition a means of following up in the field any condition of the distribution transformers which should be remedied.

13,200 Volt Operating Results

The amount of trouble on 13,200 V. transformer installations induced us to experiment quite exten-

FIG. 7.

sively with lightning arrester protection for this class of equipment. Of the 118 installations which we have in our Philadelphia territory, we installed protection on 68 installations on June 20, 1925. Before this time we had a total of nine cases of trouble, as shown in the following tabulation, while after June 20 there were ten cases of trouble:

Lightning Trouble on 13,200 Volt Transformer Installations Fuse Failures and Transformer Damage

	1925	
	Before June 20	After June 20
Cases of Trouble	9	10
Protected Installations	0	68
Unprotected Installations	118	50

Cases of Trouble per 100 Transformer Installations 1925 After June 20

Protected	3
Unprotected	16

A check on the 2400 V. failures on the system before and after June 20 will show that approximately twice as much trouble occurred after this date as before, while on the 13,200 V. transformer installations the amount of trouble is about the same for both periods. Since the transformers of both classes are scattered over approximately the same territory, we attribute to the protection of the 68 transformer installations the fact that the trouble since June 20 is only one-half of what we should have expected.

Reducing the cases of trouble to terms of 100 transformer installations for that part of 1925 after June 20, we find that the number of failures for protected installations was three, while that for the unprotected installations was sixteen, or slightly more than five times the former value. This we consider is a fair index of the degree of protection afforded.

District H

Location Central Ave. 1st pole South of Myrtle Ave.

Size	Make	Serial
4 Kva	G.E.	708541

Date of Failure 7-2-25

Cause of Failure High terminal board

Condition of
Oil Clear

Terminal Boards Above oil

Bushings O.K.

Type of Arresters None

Transformer Purchased 8-16-09

Transformer installed at above location 3-10-22

Remarks:

FIG. 8

Conclusions

Our experience with lightning arrester protection has rather definitely established in our minds the following points:

In order to get satisfactory results in connection with lightning arrester protection:

(1) Such contributory causes of trouble as high terminal boards, defective bushings, and low oil should be illuminated by means of proper inspection.

(2) Considerable attention should be given to insure low ground resistances, and

(3) Arresters should be installed directly on the equipment for which protection is desired.

*Requirements of Lightning Arresters and Factors Effecting Their Performance**

By E. D. TANZER†

POWER and lighting circuits, together with the apparatus connected to them, may be subjected to transient overvoltages, due either to lightning or system surges. This overvoltage results from the sudden release of electrical energy, the flow of which is controlled by the inductance, capacity and resistance of the circuit. The wire size, spacing and height of the circuit above ground determine the relative importance of these factors, the capacity being that between conductors and to ground, while the inductance and resistance depends upon the wire size and spacing. The energy of the surge is stored alternately in the static field of the condensers and in the magnetic field of the inductances. When energy is released on the circuit a portion of the circuit is raised in potential above that of the remaining part and current flows from the higher to the lower potential through the distributed inductance and charges the distributed capacity of the circuit into which it flows.

Two common ways in which energy may be released to a circuit are first by release of the bound charge on the circuit, due to storm conditions, and second, by collapse of the magnetic field of apparatus during switching operations. Any sudden change in the power level of the entire system also generally results in a surge, the magnitude and hence the destructive effects varying between very wide limits.

Surge Characteristics

Surges are generally characterized by high voltages and steep wave fronts. While definite values are not easily secured it is probable that surges, due to lightning, may result in voltages of several hundred thousand volts, while those due to switching operations may have values of several times the normal line voltage. The steepness of the wave front also varies between wide limits. At the point of release of the surge energy, the wave front may be almost infinitely steep; that is, the wave shape practically rectangular. The same wave, after traveling a considerable distance, would have greatly decreased steepness of front.

The transient overvoltage resulting from the surge generally constitutes the greatest danger to insulation of circuit or apparatus. However, if the wave front is very steep zero and maximum voltage may occur within a few feet of each other on the circuit and so subject the insulation involved to excess strain. This serves to explain the well known fact that when transformers are damaged as the result of lightning storms, the point of failure is invariably found to exist in the first few turns of the primary winding.

Requirements of Lightning Arresters

In order to limit the transient voltage to a value not dangerous to the circuit or apparatus, means must be provided to drain away the energy of the surge before it is capable of causing dangerous potential differences. This may be done by means of lightning arresters, which provide shunt paths to the ground and between the lines so arranged as to take little, if any, current from the line under normal conditions, but to take considerable current under surge conditions. An ideal arrester would consist of a device that could be directly connected to the line without the necessity of gaps to prevent current flow under normal conditions, and so constructed as to function equally well irrespective of the amount of overvoltage or steepness of wave front impressed on it It should also be capable of successfully interrupting any flow of dynamic current, tending to follow the rush of surge energy through it, without damage to itself. Such an arrester unfortunately is not available at present. Accordingly, the arrester selected should have as many as possible of the following detailed requirements:

1. The arrester should not permit current flow during normal circuit operating conditions.

2. It should be so constructed as to be uneffected by weather conditoins and require little, if any, inspection or maintenance.

3. It should not discharge until the transient voltage impressed upon the line has reached a predetermined definite value.

4. It should have sufficient discharge capacity to handle any surges likely to occur in its vicinity. It should also have sufficient thermal capacity so the heat liberated in it during discharge may not cause its destruction.

5. It should have a low value of dielectric spark lag.

6. If possible it should have an impulse ratio of unity or less as this determines its effectiveness of response to waves differing widely in frequency and steepness of wave front.

7. It should be capable of breaking the dynamic current flow tending to follow the surge discharge.

8. It should be automatic in action and so capable of handling a succession of surges

9. During its operation the arrester should not originate oscillations on the circuit to which it is connected.

Probably all of these requirements cannot be met in a single design without resulting prohibitive size and cost. The necessity and relative value of these factors is dependent upon the importance of the apparatus to be protected and its location. Selection of arresters must also be made with some reference to their cost. That is, maximum economy of system operation may result long before one hundred per cent protection is obtained.

Service Requirements of Lightning Arresters

The factors of particular interest to the user of lightning arresters are:

*Presented at Philadelphia Section, November 7, 1925.

†The Philadelphia Electric Co., Philadelphia, Pa.

1. Speed of discharge.

2. Ability to break the dynamic current flow which attempts to follow a surge discharge.

3. Ability to operate repeatedly.

An arrester, however, may meet these requirements and still fail to function properly when installed. This results because of the fact that when an overvoltage arrives at the arrester, neglecting reflections, it has two parallel paths it can follow, one through the arrester to ground, the other to continue along the line. The amount of energy drawn off to ground and dissipated, therefore, depends upon the ratio of the impedance of the path to ground through the arrester, to the surge impedance of the line. As the impedance offered to the surge flow along the line is of the order of 300 ohms for most serial circuits, it is evident that the impedance of the entire path from line to ground, including the arrester should be only a fraction of this value in order that the arrester may function most efficiently.

Method of Using Arresters

In order to properly protect a transmission or distribution system, together with its attendant apparatus, arresters may be employed to:

1. Protect the system as a whole.

2. Protect individual apparatus on the system.

In the first method use must be made of a large number of arresters spaced at proper intervals along the line, and not necessarily in close proximity to individual apparatus. The theory underlying this method of usage is that if sufficiently large number of drainage points are provided, the energy content of all surges will be dissipated before the voltage reaches dangerous values. This requires the installation of a large number of arresters, each of which may constitute a menace to the operation of the system if it by chance fails in service. This method has not proved satisfactory for the protection of transformers on a modern distribution system. At times even arresters installed on poles adjacent to the transformers have proven inadequate.

In the second method each important piece of apparatus as well as points of distinct electrical discontinuity in the line are provided with an individual arrester installation and no attempt is made to drain the system as a whole. Operating results from this system have shown a decreased number of damaged transformers and blown fuses. In this method the arrester installations may be graded in accordance with the importance of the transformers they are to protect. First, there are a great number of small transformers relatively cheap in first cost and not producing a great deal of revenue. Accordingly, the arresters used for this protection should be inexpensive, easy and cheap to install and require no inspection.

The second class comprises the average size transformer and there is also a large number of these to protect on the average system. Here greater care should be taken in the arrester installation in order that it may function with a greater degree of certainty.

The third class is made up of the large transformer installations, especially those serving important customers where continuity of service is of the greatest importance. In this case a greater expenditure for arrester equipment and installation is justified.

Finally, substation or generating equipment demands the most efficient protective apparatus obtainable and the maximum of care in its installation and maintenance.

Arrester Performance

In any arrester installation the performance secured depends upon:

1. Characteristics of the gap inserted between the arrester and the line.

2. Characteristics of the arrester.

3. Impedance of the connection used between the arrester and the ground.

4. Proper electrical contact in the ground disconnecting device.

5. Method of grounding and the actual resistance of the ground.

The ability of an arrester installation to function properly when subjected to all kinds of surges is largely determined by the characteristics of the gap between it and the line. If this consists of a horn or approaches the needle type, the arrester will be sluggish in action allowing a large surge voltage to build up before it starts to discharge. Also its action under normal frequency surges will be greatly different from its response to surges of steep wave front. Since a spherical gap has little if any dielectric spark lag and performs equally well with surges of widely different frequency, it or a close approach to it should be used.

The impedance of the total arrester installation should be low in comparison to the surge impedance of the line. This requires that the impedance of the connections between arrester and ground, the ground disconnecting device and the ground itself be as small as possible.

Since the surge energy is very apt to be at high frequency, the size of the ground wire should be so chosen that it may have ample current carrying capacity even when "skin effect" is taken into account.

Lightning arrester installations must have a disconnecting device in the ground wire in order to protect the lineman when working on the pole. This disconnecting device often times develops high contact resistance and so prevents the arrester from functioning properly. It should be so designed and constructed as to maintain ample electrical contact at all times.

However, the impedance of the ground connection is generally negligible in comparison to that of the ground itself. If an arrester is installed in a location where the ground resistance is high, the effectiveness of it as a protective device will be greatly decreased. It is important, therefore, that the ground be so made as to have as little resistance as possible.

Lightning Arrester Grounds

Grounds for lightning arrester purposes consist either of attachments to the water system or of driven pipes. Wherever possible it is preferable to make the ground connection directly to the water system with some form of attachment that is positive and not apt to get out of order. A well designed ground clamp, or if possible a soldered connection, should be used. The resistance of the

ground so made is very low, probably well under one ohm in the majority of cases. This low resistance results from the large surface of the water system in contact with the ground and consequently large conductivity results. Unfortunately, water systems are not always available for grounding purposes and occasionally some difficulty is had in obtaining permission to make the attachments. In this case dependance must be placed upon a driven pipe or a buried ground plate. Of these, the driven pipe is most commonly used. It consists of a pipe, generally over one inch in diameter, driven into the ground to a depth of six to eight feet. The resistance that it offers to the flow of current through the arrester discharge path is made up very largely of the resistance of the ground in the form of a cone of earth with apex at the surface. That is, the maximum resistance is involved in the earth immediately adjacent to the pipe.

Due to the poor conductivity of certain kinds of soil a single driven pipe will not be effective in providing a sufficiently low resistance path. Here resource must be had to other driven pipes connecting in parallel with the first. These should be at a distance of at least eight feet apart, in order that the system have its maximum effectiveness. A ground connection of this sort may be made to have as low a resistance as desired. The conductivity of the soil and its moisture content may be increased by the use of chemicals placed about the ground pipe and mixed with the soil. One method of decreasing the resistance is to excavate about the ground rod and fill with coke or charcoal. The conductivity is increased in this case in some degree because of the lessened resistance of the coke or charcoal and also bcause this material is of a porous nature and tends to gather the moisture and also retain it, therefore keeping the ground more moist than would otherwise be the case. This, however, is not as effective as to fill the excavation about the ground pipe with salt or copper sulphate. Ordinary salt is widely used and has been found to be very effective, not only in making the soil more conductive, but in maintaining the ground about the driven pipe in a moist condititon.

Salt, however, is disadvantageous in that it corrodes the driven pipe or ground plate, and so may cause trouble by loosening the connection or by decreasing the surface of the ground pipe exposed to the soil In order to avoid this corrosion trouble copper sulphate is sometimes used instead. Here the decrease in resistivity of the soil is largely because of the greater conductivity of the mixture of soil and copper sulphate.

By means of these methods it is often possible, where local conditions prevent the use of multiple grounds, to lower the resistance of the individual ground pipe to the desired value. The use of these methods, however, necessitates an inspection and replacement of the salt or copper sulphate from time to time. Ordinarily, a yearly inspection made before the lightning season will serve to maintain the grounds in the desired low resistance condition.

Under certain conditions combinations of these methods may have to be resorted to in order to lower the impedance of the discharge path of the arrester to the desired value. This value should, of course, be as low as possible. Good operating results, however, have been secured providing the resistance of the grounds is kept below 20 to 25 ohms. This is the case of a large distribution system where the arresters are installed to protect individual transformers or other equipment. In the case of the arresters used to protect substations or generating equipment, the resistance of the ground connection must necessarily be much lower than the value indicated above, probably not over one ohm. This generally necessitates a connection to the water system as being the only feasible means of obtaining the desired result.

In order to insure that the grounds are in good condition at all times, systematic measurements should be made.

Method of Measuring Ground Resistances

There are three methods of obtaining the ground resistance in the field; these are:

a. Voltmeter-ammeter method using a.c. current.
b. The wheat stone bridge method.
c. Voltmeter-ammeter method using d.c. current.

Voltmeter-Ammeter Method With A.C. Current

This requires a transformer to be connected to a line of suitable voltage, ordinarily a secondary circuit and some means of varying its output. The output of the transformer is passed through the ground to be measured and an auxiliary ground, the current being measured by the ammeter placed in series. The voltage drop caused by the flow of current through the ground is measured by means of a voltmeter. The voltage divided by the current is then the impedance of the ground to be measured in series with that of the auxiliary ground. If possible, the water system is utilized as the auxiliary ground. In this case as its resistance may be assumed to be negligible the reading is at once a close approximation to the impedance of the ground being measured. Also as the reactance is negligible in comparison to the resistance, the impedance value may be considered as being equal to the resistance. In case the water system is not available as an auxiliary ground, use must be made of driven grounds. These should preferably be of negligible resistance. However, two auxiliary grounds may be used and together with the ground to be measured, designated as a, b and c. Then the resistance of each can be obtained by measuring the resistance involved from a to b, b to c, c to a, and solving the three simultaneous algebraic equations so obtained.

This system of ground measurement has as its chief advantage the fact that comparatively high voltages and currents are used. That is, the measurement is made under conditions approaching actual operation. Also the results obtained are not effected by stray currents in the vicinity of the ground to be measured or by thermo or contact e.m.f's set up at the surface of the ground connection. The most accurate determinations will, of course, be obtained in this method when the individual ground connections all have practically the same resistance.

The disadvantages of this method of measurement is that it requires a source of a.c. energy which is not always convenient to obtain in the field, and a test transformer, which is bulky and inconvenient to transport. Accordingly, this method is often times not readily useable, especially in suburban districts.

Wheat Stone Bridge Method

This method requires a wheat stone bridge of the ordinary type, together with a source of energy such as three or four dry cells, and some means of interrupting the current supply to the bridge, as a low resistance buzzer. Instead of using a galvanometer as a detector, a telephone receiver of fairly low sensitivity is employed. The procedure used in making measurements with this method is practically the same as for the ammeter voltmeter method in that three ground connections are used and the resistance of each pair in series is measured. The individual resistance is obtained from the solution of the resulting algebraic equations. This method enables accurate determinations to be made only when the resistances are not distorted by parasitic contact or thermo e.m.f's. The method is rather susceptible to stray currents in the vicinity of the ground to be measured and accordingly it is generally found preferable to use phones of low sensitivity, as they are less apt to pick up noise due to currents. All things considered, the accuracy obtainable by this method is probably well within 5 per cent, which is ordinarily sufficient for all practical purposes.

The principal advantages of this method are:

a. The source of energy constitutes a part of the apparatus and it is therefore not necessary to depend upon a low voltage supply circuit at the point where the measurement is made.

b. The outfit is small in size, easily portable and fairly rugged.

c. Direct readings are obtained. This does away with the necessity of the calculations required in the first method.

The disadvantages of the method are:

a. It is particularly susceptible to stray currents, which are manifested by making the telephone receiver so noisy that it is difficult to find the point of balance with any degree or certainty.

b. The method gives no indication as to the effectiveness of the ground connection to currents of a magnitude that it will be called upon to handle.

Ammeter Voltmeter Method Using D.C. Battery Current

This method does away with the chief disadvantage of the a.c. method in that it uses as a source of energy one or two 6 volt batteries. The procedure in making the resistance measurements is essentially the same as that with a.c. current, in that current from the battery is passed through the ground to be measured and an auxiliary ground in series. Since the voltage of the supply is low, a d.c. milli-ammeter of fairly low scale range is required in order to read the values of current, the voltage drop being read by a high resistance d.c. voltmeter of low scale range. Any inaccuracies due to the possibility of contact e.m.f's being set up between the surface of the grounding device and earth in contact with it are minimized first by purposely keeping the value of the test current low and second by reversing the direction of the current flow through the circuit. The apparatus used in this test is portable and can be conveniently carried in an open Ford car which should be provided with some sort of a test table on which the instruments may be placed and the connections from the battery and test grounds made. By a combination of switches it is possible to reverse the current in the measuring circuit without the necessity of reconnecting the instruments. This makes for speed in the measurements. When using this method it will be found that the current in the ground circuit is highest at the instant contact is made and decreases to a staple value in something under one minute. The average of two readings obtained with direct and reversed current in the ground circuit will tend to eliminate parasitic e.m.f's.

The influence of stray currents on the measurements may be readily minimized by reversing the current in the ground circuit. In practically all cases it will be possible to obtain readings when the stray currents are at a minimum. While this method probably does not give absolute results it does afford an easy and rapid method of comparison of ground resistances. The chief advantage of the method lies in the portability and limited amount of apparatus necessary.

Maintenance of Grounds

In order that the grounds may be kept at the desired low resistance, it is necessary to make periodic measurements. These are preferably made at times when they would normally be high and at least yearly. The results of such measurements are conveniently recorded on a map of the district involved. When so recorded they serve to show at a glance the general condition of the grounds for the entire system. Areas of natural high resistances are indicated and attention is directed to localities in which efforts must be made to secure lower values.

Conclusions

It is evident that a large number of factors other than the selection of the arrester itself must be taken into account if proper protection is to be had for the system as a whole. Desirable charactertistics of the arrester may be nullified in part by improper installation and maintenance. Accordingly, some sort of systematic inspection and measurements of grounds is highly desirable if best operating results are to be secured.

IRON and STEEL EXPOSITION

Hotel Sherman Chicago, Ill.

June 7th, 8th, 9th and 10th, 1926

FUEL - - ELECTRICITY

SAFETY - - MACHINERY

Apparatus Used in the Iron and Steel Industry Will Be On Display.

Natural Electricity and Lightning Protection

By J. SLEPIAN*

IN the older books on Physics you will find a classification called "natural electricity," which treated such subjects as the aurora borealis, northern lights, lightning, etc. In the last 15 or 20 years, however, we have learned that natural electricity is a better name than was thought because it appears that electricity is the most natural thing there is. We have begun to learn that electricity is the very stuff that the universe is made of and all matter, including man himself, is electricity. The word "natural" is the best adjective that could be applied to it. I will take a minute or two to tell you something of the electrical structure of matter as we now believe it to be.

As you all know, we believe that matter is atomic, i. e., that it is made up of tiny particles and that these particles are of the order of 10.8 centimeters in diameter. In recent years we have found good reasons to believe that these atoms are made up of little particles of electricity. We believe that they consist of a central bit of positive electricity with a sort of solar system around it, a solar system of negative charges, each negative charge being called an electron. It is thus a sun of positive electricity with a planetary system of electrons.

In general, in any such atom the total number of negative charges is just equal to the number of positive charges so that the atom is neutral electrically. However, it is possible to break off one or more of these electrons from the atom itself and thus produce free electrons and positively charged atoms.

That is, gases under various circumstances or when subjected to various influences may become ionized. A certain proportion of the molecules of the gas become split up into negative and positive charges, which are separated from each other. This may take place under the influence of the sun and certain natural radiations from the earth, and that has a very important bearing on the development of natural electricity, i. e., the development of thunderstorms.

The fact that the upper atmosphere is ionized is now fairly widely known to those interested in radio. This ionized upper layer of the air is called the Heaviside layer and it is useful in explaining some of the anomalous carrying power of short waves.

I will not go any further in detail as to the electrical construction of the atom, as all I need for my purpose is the fact that it is electrical and that under proper circumstances atoms are broken up into positive and negative charges. I want now to take a little peep into colloid chemistry.

What is colloid chemistry? Looking into a book by Bancroft on "Applied Chemistry," colloid chemistry is the chemistry of bubbles, drops, grains, filaments and films. Then further on Bancroft gives a rather long list of the various things to which colloid chemistry applies, and includes cement, bricks, pottery, oils, greases, soaps, paints, varnishes, lacquers, butter and cheese, beer, ale and wine, etc. Inasmuch as you are no longer interested in the last items, beer, ale and wine, I will cross them out and put in their place, "thunder clouds."

How do I justify this violence which I have perpetrated upon Bancroft's list by including thunder clouds in colloid chemistry? You will recall that Bancroft said that colloid chemistry is the chemistry of bubbles, drops, grains, filaments and films. He said drops and a thunder cloud is a collection of little drops of water from the atmosphere and so that is how thunder clouds come into colloid chemistry.

Now what can colloid chemists tell us about thunder clouds? In general, colloid chemists find that their bubbles, drops, grains, filaments and films have a great facility for taking up electrical charges. Almost invariably in an emulsion or suspension of fine particles the drops or particles are electrically charged. We are not surprised, therefore, that in a thunder cloud made up of tiny drops, each drop bears an electric charge.

How do these little drops of water making up the cloud get their electric charge? Remembering that the air in the upper atmosphere is ionized to a considerable extent, we can easily imagine a process. When air carrying water vapor is chilled, the water may be precipitated into drops. Now it is quite clear that if there are any ions or free charges floating in the air the electrostatic force from each charge will attract the water molecules to it so that there will be a tendency for the drops to form around these electric charges, that is, the ions will form nuclei about which the drops will form.

This tendency of the drops making a fog to form about the nuclei of dust particles or impurities in the air is quite a common thing. When I first come to Pittsburgh I was quite surprised at the prevalence of fogs although Pittsburgh is not particularly near any large body of water. In Boston, which has much more water in its vicinity, the fogs are comparatively rarer. The difference between Pittsburgh fogs and Boston fogs became clear to me after I got married and got some personal knowledge of the affairs of a laundry. Each little drop of water in Pittsburgh fog surrounds a smoke particle. The large number of smoke particles in the air around Pittsburgh encourages the formation of fogs so that in spite of the absence of a large body of water the fall and winter mornings in Pittsburgh are almost usually foggy, while those of Boston are less frequently so.

We now see in a very general way how thunder clouds may come about, that is, we have ionized air in the upper regions, precipitation of water in the fogs in these upper regions and the natural tendency of the particles making up the fogs to form around these electrical charges, and thus an electrically charged cloud.

It is rather interesting historically to note that the first experiments for isolating the electron and to prove its existence virtually involved making an artificial thunder cloud. This experiment was carried out a good many years ago by J. J. Thompson and was improved upon subsequently by C. T. R. Wilson.

Presented at Cleveland District Section, October 14, 1925.
*Westinghouse Elec. & Mfg. Research Laboratory, East Pittsburgh, Pa.

These gentlemen took a box, saturated it with water vapor and let an ionizing radiation, such as perhaps x-rays, shine into the box so that numerous ions were produced. Then by a sudden adiabatic expansion they caused the water to condense into a fog. From the time it took the fog to settle they could compute the size of the water drops; and from the weight of the water which settled they could then determine the number of drops; and finally by measuring the total charge which the drops carried down they could determine the size of the elementary charge. Now I think it is very interesting, although this was not the purpose, they really produced an artificial thunder cloud in that little box, probably following a course very close to that which Nature uses in producing her thunder clouds. They ionized air containing water vapor and chilled the air so that the water vapor condensed around these ions.

Now that we have seen that the clouds which form up in the heavens are electrically charged, what influence do they have upon our electrical power systems? We must then consider the influence of the thunder cloud on a transmission line.

Since the cloud bears an electric charge, it will produce an electrostatic field which will extend down to the earth as shown in Fig. 1-a. If the cloud is positively charged, as in the figure, a negative charge will be drawn by induction to the surface of the earth and upon any conductors which are electrically connected to the earth. Fig. 1-a shows a transmission line having on it a negative charge induced by the positively charged cloud above.

But now, although the line carries this negative charge, it is not in any way stressed as regards its insulation to ground. The charge on the line is striving to get up to the opposite charge in the cloud and is making no effort to escape to ground. The line is, therefore, for the moment in no danger. But now suppose the cloud loses its charge by either discharging to ground or by discharging to another cloud, as in Fig. 1-b, then the electrostatic field which the cloud had produced, disappears and the negative charge, which had been induced on the transmission line, tries to get back to earth. Then, of course, the insulation supporting the transmission line becomes highly stressed. If the charge can not strike over an insulator in this region where it is set free, it passes along the line according to known principles, forming two traveling waves which will stress electrically any apparatus connected to the line which it reaches. The danger to the line thus arises from the sudden discharge of a cloud.

You will note that it is not necessary for the cloud to discharge directly to the line. The line may be overstressed without the lightning striking to any object in its neighborhood. It may be overstressed purely by induction. As a matter of fact direct strokes on transmission lines are comparatively rare, but the induced strokes, such as I have described here, will occur in every lightning storm.

Now how high is the voltage which is produced in a line as a result of this inductive charge which the cloud leaves on it? There are two ways in which we can get information about this. We can reason about it from the known properties of air. We can say that the electrostatic field produced by the cloud can not exceed the dielectric strength of air and thus get an upper limit as to the intensity of the gradient in the electrostatic field of the cloud; or we can try to obtain direct experimental evidence as to what intensity this gradient is. I should mention, of course, that if the gradient is known, then the voltage on the line will be merely the product of the height of the line by the intensity of the gradient.

A number of people have concerned themselves with measurements of this gradient and Messrs.

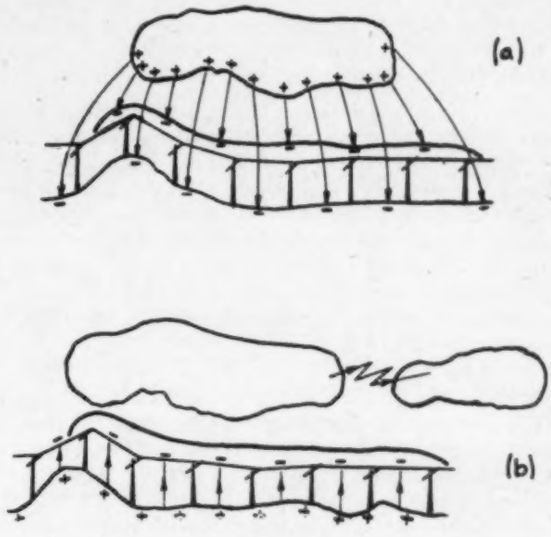


FIG. 1.

Creighton and Peek of the General Electric Company and also Norinder, a Scandinavian, have obtained experimental values. Their estimates of the electrostatic gradient in a thunder storm come out in the order of a hundred kilovolts per foot, which is also the order of magnitude of the dielectric strength of air between points.

This is a very high gradient as you will see if you interpret it in terms of voltage which will appear upon lines. Thus, if a line is 30 feet above ground then 30x100 kilovolts will equal 3,000,000 volts, so that we learn that such high voltages may be induced upon lines by lightning strokes. Besides these results of Creighton, Peek and Norinder, there is now becoming available information arising from the use of a new electrical instrument, which has been installed in the last year or two by the Westinghouse Company upon a number of electrical systems in this country. This instrument was invented by Mr. Peters of the Westinghouse Company and bears the formidable name of Klydonograph, which is the Greek word for surge or wavemeter. I do not believe that Mr. Peters ever studied Greek, but I know that he gets his lunch in a Greek restaurant which may, perhaps, account for it.

This instrument makes use of a phenomenon which has been long known. If an electrode is placed upon a photographic plate in the dark, of course, and a high enough voltage applied, upon developing the plate, a peculiar sort of figure will be found. These figures vary in appearance depending upon the polarity of the voltage applied to the electrode and vary in size, depending upon the magnitude of the voltage applied. Mr. Peters investigated these relations and found them sufficiently consist-

ent and reliable so that a practical recording instrument could be made which would record any excess voltages occurring on a transmission line to which the instrument was connected. This instrument is provided with a roll of film and an eight-day clock movement, so that it needs be inspected and the roll changed only once a week. I shall show on the screen here some pictures of this instrument and some of the records obtained with it. The one slide I have here showing the record of an induced lightning stroke indicates 600,000 volts, but since the time of that figure we have obtained a large number of other lightning strokes and we have records of induced voltages exceeding one million volts.

The voltage of which I have just been speaking, I must repeat, is a voltage which is produced in the line entirely by inductive action from the cloud. When occasionally lightning strikes the line the voltages may be very much higher than those indicated here. A year ago in a paper before the A. I. E. E., Mr. Creighton made some estimates as to the voltages and current in a direct lightning stroke. He estimates that the current would amount to a million amperes and that the frequency of the discharge is of the order of 100,000 cycles although this oscillation will be very rapidly damped.

The current in the direct stroke itself is thus tremendous and its magnitude is such that it is practically impossible to protect a system against such a direct stroke. It is not economically possible to build an arrester which will take care of such current. We must trust to luck or Providence. The induced stroke is, however, much less intense and it is possible to build equipment which will go a long way towards making the system immune from these strokes, and fortunately the induced strokes make up nearly a hundred per cent of lightning troubles.

The function of lightning arresters is, of course, to remove from the line as quickly as possible the charge which the thunder cloud had induced on it, that is, to reduce the voltage which is generated upon the line by the discharge of the cloud. Now in any such problem of reducing voltage it is necessary to know what the regulation of that particular voltage is. If the source of voltage were a generator with a large internal impedance, then it would be possible to reduce the voltage by drawing only a little current, but if the source of voltage were a generator with a very low internal impedance, in order to reduce the voltage appreciably it would be necessary to draw a very large current. What then is the internal impedance with respect to this voltage which appears on transmission lines? How much current must be drawn from the line to reduce this voltage?

We must consider the electrical nature of the transmission line. It has distributed inductance and also distributed capacity. Now you know that frequently, and particularly in problems of this kind, inductance and capacity act in opposite manner and here also they do so, for it turns out that as far as these traveling waves or serges go, they work together like a resistance. That is, the line acts as if it had an internal resistance and this resistance is called the surge impedance of the line.

The surge impedance of practical lines is of the order of 400 to 500 ohms. Knowing this internal impedance, we can tell how much current must be drawn from the line to reduce the abnormal voltage on it. If one ampere is drawn, the voltage will be reduced 500 volts: two amperes will reduce the voltage by one kilovolt. An arrester then must be able to discharge 2 amperes per kilovolt of induced serge at a little above line voltage if it is to be really effective in protecting the line. Since, as we have seen, surges due to lightning are of the order of 500 or a thousand kilovolts, it is evident that lightning arresters should be capable of discharging currents of thousands of amperes. Thus we see that the discharge capacity of an arrester is very important in determining its protective value. Without an ample capacity to discharge current, the arrester can give little or no protection.

Of course, besides the abnormal voltage on the line there is also the normal or working voltage, although discharging the abnormal voltage an arrester must produce as little disturbance as possible upon the normal working voltage.

There have been two general types of arresters used commercially and these may be distinguished

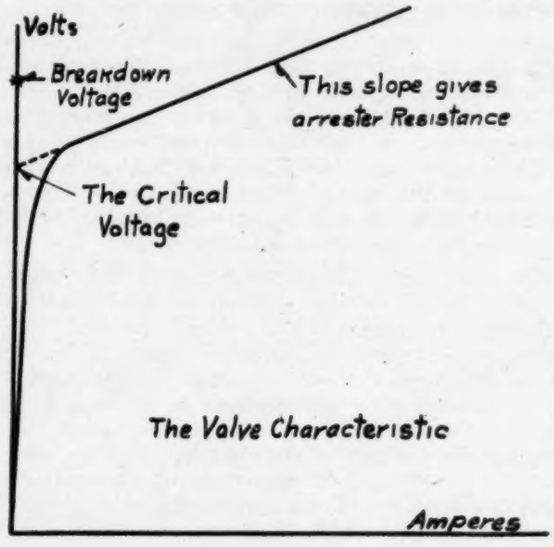


FIG. 2.

with respect to the manner in which they take care of the normal working voltage on the line. One type may be called the spark gap type and is very widely used on lower voltage lines. In its simplest form this spark gap type consisted of a horn gap connected between the line and ground. When the voltage on the line exceeded the breakdown value for the gap, the gap would discharge, and the arc which followed would rise up on the horns and extinguish itself. This worked, however, only on very small systems. As soon as the system became of any size the current, which the normal working voltage would send through this arc would be so heavy that the arc would not extinguish and the horn gap would be destroyed with a short circuit on the line. To limit the destructive action of this arc and to insure its going out, it was customary to insert in series with the horn gap limiting resistance, as the need of a high discharge rate for an arrester was not appreciated in those days. This resistance, except for the very lowest voltage lines, had to be of such a high value that it made the horn gap ar-

rester almost worthless for protection against lightning. Another form of the spark type gap arrester consisted of a series of knurled brass cylinders between which a discharge would take place when the voltage became too high. This type is very widely used. It is fundamentally the same principle as the old horn gap type, but it is possible to use lower values of series limiting resistance so that better protection is obtained. However, this arrester also is satisfactory only for the lower voltage lines.

The other type of commercially used arrester we may call the valve type of arrester, and before going into its properties I would like to say something about the duration of surges induced by lightning. Looking again at Fig. 1-a we may expect in an extreme case that the cloud may be a mile or two in extent. The length of line under the cloud, which bears an electric charge, will, therefore, be of the order of two or three miles. Now when this induced charge is set free, it travels out from its point of origin as a traveling wave with the velocity of light which is approximately 200,000 miles per second. If the length of charge is of the order of 2 miles, it is clear that the serge will pass any given point on the line in 1/100,000 of a second, that is, in 10 microseconds. This is the length of time which a lightning arrester would have to function if it is to discharge this surge, i. e., the time of a surge is of the order of 10 microseconds and probably never exceeds 30 or 40 microseconds.

The valve type of arrester is able to discharge the abnormal voltage induced by lightning for the 10 or more mircoseconds that it takes for the surge to pass in the arrester without permitting any current to flow from the normal working voltage. This it is able to do because of the volt-ampere characteristic of the elements of which it is built. Fig. 2 shows the typical valve characteristic Since the valve arrester does not discharge current at normal working voltage, it is clear that its resistance to the abnormal voltage may be made very low without the need of being concerned about dissipating energy supplied by the normal working voltage. This advantage of the valve type arrester may perhaps be made clear by Fig. 3. The basis of calculation of the curves of Fig. 3 is indicated in Fig. 4, which shows an arrester to which two lines come in. The surge impedance of each line is taken as 400 ohms so that the two lines in parallel have a surge impedance of 200 ohms. The reduction in voltage is, therefore, equal to 200 times the arrester current in amperes. Now the amount of current, which the arrester will draw depends upon its internal resistance and, therefore, the reduction in surge voltage will depend upon the internal resistance of the arrester. Assuming that 250 kilovolt is the initial surge voltage, the heavy line curves in Fig. 3 show the reduction in voltage produced by arresters of different resistances. It is clear that so far as reduction in voltage goes, the valve type and arc type are practically on a par in that they have the same internal resistance. We also see that if we are considering, for example, a 15,000 volt line that the arresters are not really effective in protecting the line unless their resistance is not much over 50 ohms. But now when we consider the energy which the two types of arrester have to take care of, for a given internal resistance, the advantage of the valve type stands out. When the resistance is less than 50 ohms the spark gap type of arrester must dissipate over 15 kilowatt seconds of energy if it carries power current for only one-half cycle, and, of course, proportionately more if the arc persists for a longer time. The valve type of arrester, however, only needs to dissipate the energy in the surge itself. In order to get the energy which the valve type arrester must dissipate well on to the curve, I needed to consider a surge 400 miles long. A 40-mile surge gives the energy shown in the lowest curve and a more reasonable value of less than a 4-mile surge would not have shown on the curve at all. These considerations of the energy dissipation requirements of the two types of arresters have been determining. For the higher voltages, the valve type arrester is the only commercially practical arrester, which gives adequate protection to electrical systems.

Now as to the actual commercial forms of arresters. The older and very widely used arrester

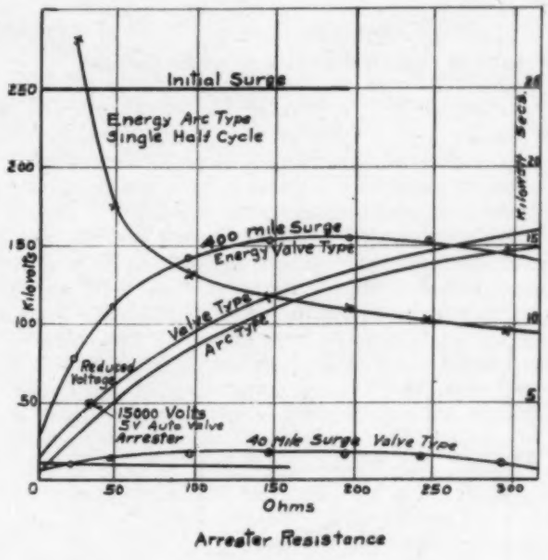
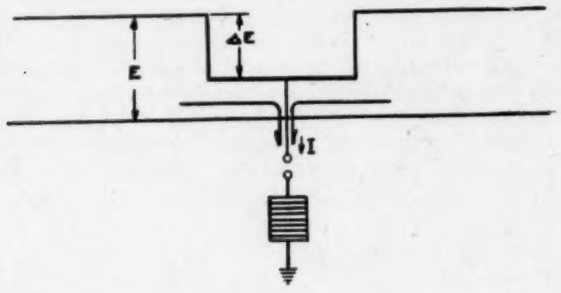


FIG. 3.

was the electrolytic lightning arrester. It depended for its operation upon the electrolytic property of aluminum forming a film on its surface, which has precisely the valve characteristic that is shown in Fig. 2. This arrester was a very good arrester and has given a very high degree of protection to electrical systems. However, it suffered a number of very practical disadvantages. First of all it was electrolytic, which meant that it was subject to freezing in cold weather. It had oil in it which meant fire risk, but worst of all, it required daily attention since the film on the aluminum would slowly dissolve in the electrolyte and had to be reformed daily. Because of these disadvantages of the electrolytic arrester, Westinghouse and the General Electric Company engineers for a good many years tried to retain the advantages of the valve type in some form which would eliminate some or all of these disadvantages. The General Electric Company found a solution in the oxide film arrester. This is also a chemical arrester, depending for its functioning upon the chemical action of heat on peroxide of lead, but it is a dry form of cell, and it does have the valve characteristic similar to that obtained in the aluminum arrester. Until very recently, however,

the oxide film was developed in sizes suitable only for large generators and sub-stations.

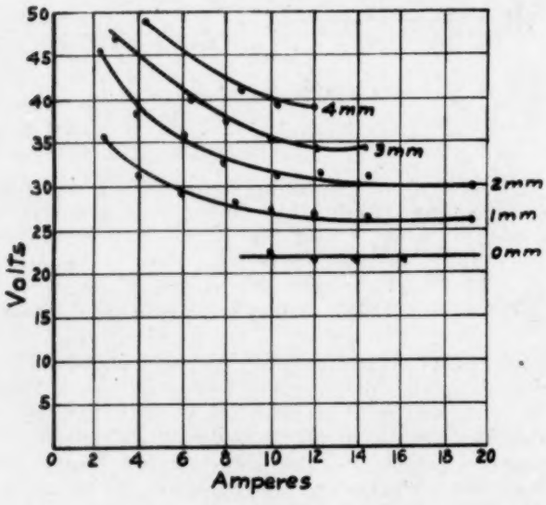
The Westinghouse Company found a solution to the problem in a somewhat different and perhaps more radical way. Their solution gets entirely away from chemical action, but depends upon properties of electrical discharges. It seems that there are two



ΔE = 200 × I
Voltage Reduction = 200 × Arrester Current

FIG. 4.

types of electrical discharges between electrodes at atmospheric pressures. These two types of discharge are known as the arc and the glow. In Fig. 5 is shown the volt-ampere characteristic of an arc discharge. The thing to note particularly is the order of magnitude of the voltages. You will not that short arcs can be maintained at a little over 20 volts In Fig. 6 is shown the volt-ampere characteristic of a glow discharge. You will notice that the current scale is very small, i. e., expressed in milliamperes, but that it takes over 300 volts to maintain a short



Arc Copper Electrodes

FIG. 5.

glow. Thus we have a low voltage form of discharge, the arc at a little over 20 volts: and a high voltage form of discharge, the glow at a little over 300 volts. Now what determines in any case whether you get a glow or an arc? It turns out that it all depends upon the temperature of the cathode. If the cathode is kept cool, then the discharge takes the form of a glow, but if any spot of the cathode is allowed to become hot, then the discharge takes the form of an arc. When a discharge starts between two electrodes, it must of course, begin as a glow, because the electrodes are initially cold, and it is only after a hot spot develops on the cathode that the discharge will change over into an arc. If some means could be found to prevent the development of a hot spot, the discharge would persist as a glow. Now a very simple means was found for preventing the development of such a hot spot for the length of time which is long compared to the duration of a surge due to lightning. This method was to use as electrodes material having a rather high resistivity, something of the order of a few ohms per cubic centimeter, i. e., about a million times the resistivity of metal. If such electrodes are used, it is easy to see that the resistivity of the material prevents a concentration of the discharge into any point of small area because if such concentration were to take place, it would call into being a high ohmic resistance in series with that point. Thus with resistance electrodes the discharge stays impressed out all over the cathode and no hot spot develops and the change-over from the glow into the arc is delayed for a long time. It is then clear that

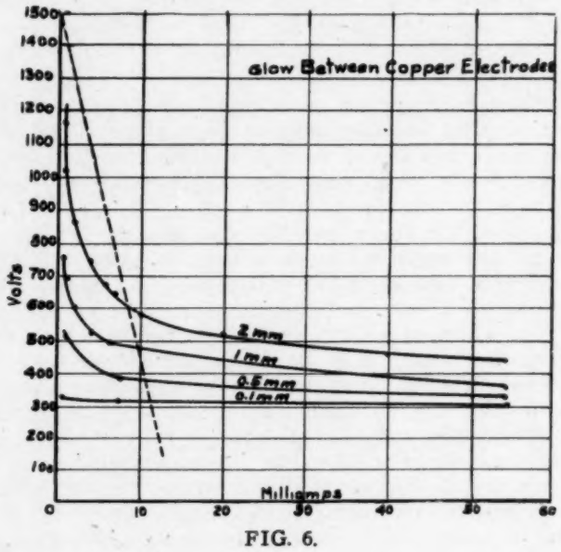


FIG. 6.

by using resistance material electrodes spaced so closely that the breakdown voltage between them will be a little greater than 300 volts, the valve characteristics of Fig. 2 will be obtained. This arrester took quite attractive practical forms, some of which I shall show on the screen. It is made for all voltages from the lowest to the highest and is made in two sizes, the larger of which is designed so as to give performance equal to that of the electrolytic, which experience had shown to be ample for adequate transmission line protection. The smaller size is suitable for pole mounting while the larger size, stationary type, requires special mounting.

This solution arrived at by the Westinghouse engineers in the form of the autovalve arrester is rather interesting in that it is a homeopathic remedy to transmission line troubles. You know that the homeopathic school of medicine is based on the principle that like cures like, i. e., to cure the bite of a

dog eat a piece of the dog. Now, as I explained before, it is not the charge on the thunder cloud that make the transmission line sick: it is the failure of the air in the heavens, the breakdown of the air which endangers the equipment below. Now the homeopathic electrical engineer sees the distressing consequences which will follow from the breakdown of the air in the heavens and he proceeds to cure like by like by cunningly introducing the weak air gaps between his line and the ground which will also break down.

This the engineer does in spite of the fact that the lightning arrester from one point of view is the most expensive piece of equipment in use, electrically. Consider the time of working of an autovalve arrester. The length of any particular discharge may be only 10 microseconds. On a high voltage line the arrester will discharge a large current, perhaps not over a hundred times a year. Thus the total length of time that the arrester is actually working is 100x10 or 1,000 microseconds or 1/1000 of a second. Now we do not know what the life of an autovalve arrester is since we have only been making them for the last few years, but if we write off one hundred dollars a year as depreciation, that will make the arrester cost $100,000 per second of actual service. Now that is a pretty heavy charge for the service of any machine, but I have the courage to stand here and say that it is worth it.

DISCUSSION

E. H. Wentz*: I have one question to ask Dr. Slepian, and that is: Does the electrolytic arrester act in a more rapid manner than the other type of arrester?

Dr. Joseph Slepian: The electrolytic arrester gives a greater electrical display than either the autovalve or the oxide film. In the electrolytic arrester after the discharge of the lightning surge an arc forms which rises up on the horns; but this arc is not the lightning discharge current, it is only a capacity current flowing in the arrester and amounts to .6 ampere. So far as the current induced by lightning itself is concerned, a thousand amperes or so, the autovalve has practically the same resistance as the electrolytic arrester and I see no reason why they should be different in their action. Test papers placed in series with either arrester show about the same result, a small hole punched through the paper and no difference can be seen in these test papers.

Until very recently we had no experimental data as to the performance of arresters on transmission lines, but now with the use of the Klydonograph our records are beginning to grow. We have a number of records of discharges of autovalve arresters showing currents of hundreds of amperes.

Another type of information as to performance of arresters is being obtained. For example, D. W. Roper, Commonwealth Edison Company of Chicago, has made a very careful statistical study of the benefits derived from lightning arresters and has studied the influence of different types and the effects of arrester density on distribution systems. From a study of the results of several years he finds a regular curve between the number of transformer burn-outs per year and the density of arresters in any district. He finds that on his distribution systems the percentage of failures due to lightning decreases vary rapidly with the density of arrester insulations up to a certain point.

(Replying to question by Mr. G. H. Gildersleeve, District Manager Cutter Company, Cleveland, O.) Concerning Mr. Gildersleeve's first question as to the influence of surrounding objects, there is no doubt at all that adjacent buildings have a great influence upon the voltages induced on distribution circuits. The surrounding buildings reduce this very considerably. Mr. Roper found it to be the case in his studies. The evidence was quite unmistakable that the intensity of the surges in the congested districts of Chicago was less severe than those in the outlying districts.

With regard to the question as to whether arresters should be omitted from very high voltage lines, I am sorry that I can not answer this question with absolute definiteness. It will depend very largely upon local conditions. I imagine that there are some places in this world where lightning storms are so rare that they would not install lightning arresters even for the lowest voltages. The Sahara Desert is, perhaps, such a locality. Considering any particular locality, if we had enough knowledge, we might, perhaps, plot a distribution curve for the number of discharges occurring annually with more than a given number of volts. The lower the voltage considered the greater will be the number of discharges which exceed that voltage. The higher the voltage considered the fewer will be the number of discharges which exceed that voltage. In any particular locality there will be a highest voltage which is never exceeded. For any line whose normal working voltage exceeds this limiting voltage, lightning arresters will not be necessary. Theoretically it would appear possible for millions of volts to be induced upon transmission lines so that from that point of view lightning arresters should be necessary even for our 220 kilovolt lines. However, as I have tried to indicate here, it is largely an economical question and a matter of frequency or probability of discharges upon high voltage lines, and we can not give any definite recommendation until we have more information than we do have.

S. L. Henderson*: I think we are very fortunate in listening to Dr. Slepian on lightning arresters, and I am sure that he has given us considerable information.

I don't think that we need to worry very much about lightning tonight from the sound outside, but in going back over the subject of lightning arresters, I just want to say that we have had some varied experience with the different types.

My first experience was with the spark gap type on a low capacity line, and when we got a severe charge of lightning over that, followed by the power charge, we found that we had a good deal of repair work on our spark gap arresters. But later on, as we increased the capacity of the line, we found that they were better arresters. Of course, they were of the electrolytic type and required some attention, but we found one thing, and as far as I know, I can't explain it, and perhaps Dr. Slepian can.

*Superintendent Electrical Department, National Tube Company, Lorain, Ohio.

*Electrical Superintendent, A. S. & W. Company, Cleveland, O.

On several occasions where we charge out lightning arresters we had some generators break down, just at the time when we were charging them, although the man charging the lightning arrester claimed that he saw no difference in the appearance of the charging current.

That gave us something to think about, and the charging after that was done on other types of arresters, not so much to prevent this same thing happening, but we thought we would try out some other types of lightning arresters. We had them in about 3 months, and right out of a clear sky, one sunshiny day, every one of those lightning arresters, of which we had 4 sets, all broke down simultaneously. And with that, we lost a generator. That is one thing that is unexplainable to me.

After they were all fixed up and put into service, since that time we have had no trouble with that particular type of lightning arrester, but we do find that occasionally we lose a generator, and it is usually during the time when we get a heavy surge on the line.

We have installed a type of arrester during the last year or so which we thought would be the type that could take care of surges on the line to better advantage than anything we had used previously, but I have had a little experience with one of those types of arresters. We had a bad surge on the line and it scattered parts of that lightning arrester all around the room, and it looked like anything else than a lightning arrester, and we are unable to explain what happens in a particular low voltage line where we think we have about all of the various types of lightning arresters made, and which are supposed to be up-to-date, to take care of surges or freaks of unknown quantity in these lines.

I just thought that Dr. Slepian could enlighten me upon what is occurring on those lines, not only that we are losing lightning arresters, but also generators.

Dr. Joseph Slepian: In any case of a failure of apparatus by surge it is very difficult to determine just what has happened by looking at the remains of apparatus or lightning arresters. In the particular case you speak of where 6 arresters and a generator were damaged simultaneously, the surge must have been of enormous intensity. It is quite possible that this enormous intensity was due to a direct stroke of lightning upon the line. A direct stroke will generally be beyond the capacity of any lightning arrester. As I mentioned before, to protect against a direct stroke may require a discharge of 1,000,000 amperes. No arrester exists which has that capacity.

Last summer I saw a direct stroke or rather the remains of the telephone wire which had received this stroke. This telephone wire was just outside the laboratory, and it was quite evident that the line had spilled over at a dozen places at once. There was a piece of wire here and a piece of wire there, and with molten copper between successive pieces of wire. The current, which discharged from this wire in various places at once, must certainly have been an enormous one. A million amperes or more seems to me a quite reasonable estimate for a current that could discharge in parallel arcs that way. No arrester could possibly have saved that telephone line. The few thousand amperes that an arrester could dispose of would be trivial compared to the current in the actual discharge. Of course, such direct strokes occur very seldom, but when they do occur conditions such as you and I have described will result.

With regard to lightning arrester troubles, it must be remembered that the arrester is in a certain sense a delicate piece of apparatus. It is able to perform its expected duty for only a short time. If it is called upon to discharge for a long time, it will fail.

I have only heard of one arrester that was able to stand up for indefinite time under excessive voltage. This arrester was described to me by an engineer of a small utility in New York State. He told me that when he first took his position with this utility he had discussed with his predecessor the condition of lightning arresters on the system. His predecessor was quite enthusiastic about the arresters in use, saying that they had never given him any trouble whatsoever. The engineer, after a few storms, got rather suspicious about these arresters and took some of them down to examine them. The arresters consisted of brass cylinders in series with a resistor. On measuring the resistor in a bridge he found an infinite resistance. Scratching the resistor with a knife, he found it to consist of a stick of wood painted black. These arresters had been made by a small local company. It was quite apparent why these arresters gave no trouble.

In the case of the autovalve arrester in practice, failures have amounted to about 1/10 of 1 per cent so far. These failures were due in a considerable measure to errors such as are bound to occur in introducing a new apparatus, such as errors in application, errors in design such as spacing of rain sheds, etc., but even including these minor errors of design, which of course have now largely been corrected, the total failures for the autovalve arrester are less than 1/10 of 1 per cent.

A considerable number of these failures were also such that the arrester necessarily had to fall if it was doing its duty. For example, on a 2200 volt line of the Duquesne Light Company arresters began to fail one right after the other. One would fail and ground the 2200 volt line, and when the trouble man would go out and remove it, another arrester on the same line would fail half an hour or so later, and so on until all the arresters on that particular line had shorted. Quite by accident we learned later that a volt series circuit of 6,000 volts had been crossed with this 2200 volt line. The 6000 volts, of course, would break down one of the arresters, but the series current from the series circuit was so low that the arrester would take some time in failing. Then when this particular arrester would be removed another arrester would again be broken down by the 6000 volts and so on. These arresters failed, but they died during their duty. They were valiantly keeping the voltage down when their line was in contact with a 6000 volt circuit.

Another type of failure that occurs now and then is where a low voltage line, say of 2200 volts, runs parallel with a high voltage line such as perhaps 11,000 volts for a considerable distance, and where the 2200 volt line is ungrounded. So long as the high voltage line is balanced, no appreciable overvoltage will be induced on the low voltage line, but

if the 11,000 volt line becomes unbalanced as might happen with a ground the 2200 volt line will be raised in potential anywheres up to Y voltage of the 11,000 volt line. This will break down an arrester and the current will flow in the arrester equal to the charging current required to keep the 2200 volt line down to its normal potential. This charging current will be very small, usually less than an ampere, but in time the arrester carrying this current will develop hot spots and fail. If now this arrester be taken off the line a second arrester will break down and will also fail in due time, and so on down the line.

The only cure for a situation of this kind is to ground the low voltage line. Where this remedy is followed the trouble at once ceases. The situation can not be met by using arresters which will stand this current indefinitely. When an arrester is made to stand this condition indefinitely, its discharge capacity must be so limited that its performance under lightning conditions is of little value.

Electrical Rolling Mills

By D. W. BLAKESLEE*

Tube Mills

THERE are two general classes of steel tubes, welded and seamless. Useful welded tubes were made as early as 1812. Flat strips of hot steel, called skelp, are bent into cylindrical shape and welded to make pipe. The edges of the skelp may be beveled, overlapped and welded, thus forming lap welded pipe; or the edges may be left about square and made into butt welded product. In 1837 a method was patented for producing a seamless tube by forcing very hot cast steeel through a small orifice around a punch. In 1841 the swedging mill was patented; then developed to produce more economical means of lengthening hollow bullets of cast or drilled steel. Another process was developed for making of large tubes from plates; this was by cupping, which consists of pressing a disc into a cup shape after which it is drawn through dies which reduce the diameters and elongate the tube.

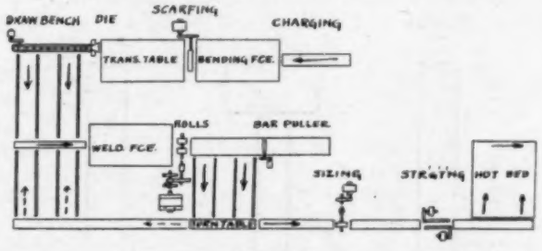


FIG. 1.

Skelp for pipe manufacture is rolled on a mill of the type required, depending upon the size of the flat required. For the smaller size tubes it may be rolled to exact size in a merchant mill. Wider skelp for larger pipe is rolled in a plate mill and sheared to the correct wirth when cold, or it is rolled to the correct width in a universal plate mill. A layout of a lap weld tube mill is shown in Fig. 1. After the skelp leaves the bending furnace it passes through the scarfing rolls, which bevel the edges. It then passes through the bending die, which gives it a cylinder shape with the edges overlapping the proper amount. At this stage of the manufacture the very large sizes are spot welded or otherwise fixed, so that the metal will be held in position for welding. After passing through another furnace the material is ready for welding. It then passes through the welding rolls, such as shown in Fig. 2.

To produce the pressure between the edges to form the union of the weld a ball is held between the rolls by means of a long bar. The ball is removed by withdrawing the bar by means of a motor operated puller. If the weld is imperfect the tube is turned around and reheated and welded again by

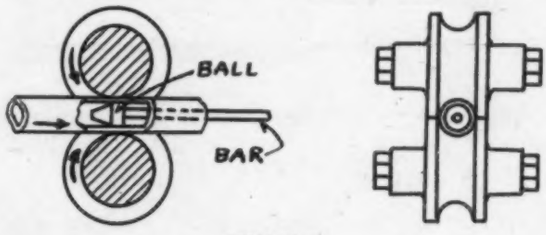


FIG. 2.

passing it through the rolls. After the weld is completed the pipe is given the required number of passes through the sizing rolls, which produce the desired outside diameter. The next operation is the strengthening which is done by motor-operated rolls.

Butt welding may be used on pipe up to three inches in diameter. For pipe which is to be butt welded the skelp is rolled with the edges slightly beveled, so that when the metal is bent the edges will make close contact from inside to outside. For butt welding the heating for bending and welding is done in one furnace, as both of those operations are done with one die. After the skelp is heated to a welding temperature the corners of the leading end

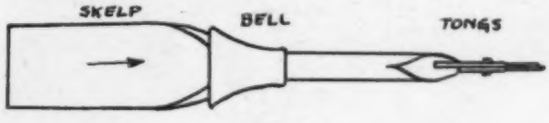


FIG. 3.

are clipped off to help start through the bell shaped die. The point is grasped in a pair of tongs, over which is slipped the die. The tongs are then hooked to the endless chain of a draw bench. The tongs, die, and skelp are withdrawn from the furnace, and the die is slipped just outside, while the bending and welding is completed in one movement produced by an electric motor. Fig. 3 shows the main

*Elec. Engr., Jones & Laughlin Steel Co., S. S. Works, Pittsburgh, Pa.

elements of the operation and their relationship. Of course, a ball must be used as with lap welding; two balls may be used, one for bending and one for welding. After sizing and straightening the pipe passes to the hot bed, where the ends are cut off.

In the manufacture of seamless tube the modern method for obtaining the original opening in the

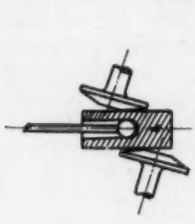


FIG. 4.

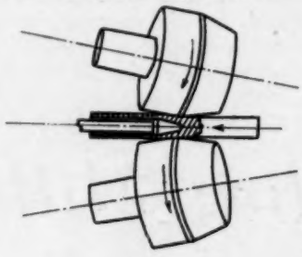


FIG. 5.

billet is by piercing. This is done in two ways: either by the Stiefel process or the Mannesmann process. The former is indicated in Fig. 4 and the latter in Fig. 5. Before the piercing is done the billet must be centered by taking the billet, while still hot from the rolling mill and indenting one end

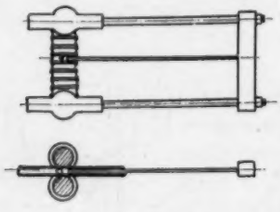


FIG. 6.

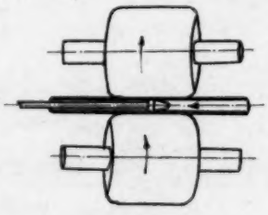


FIG. 7.

with an air-operated punch. The resulting depression, which is about an inch deep, fixes the position of the ball relative to the discs or rolls in the piercing operation.

To give some idea of the magnitude of the work of seamless tube manufacture, it may be said that

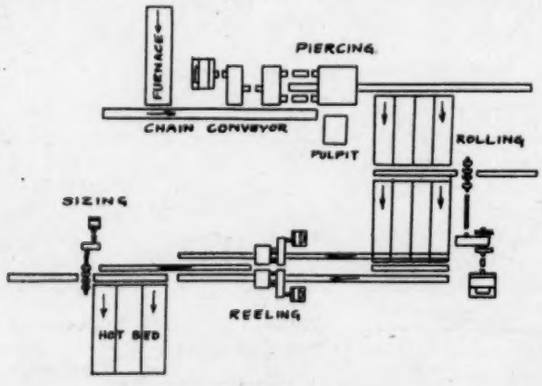


FIG. 8.

the blooms used are 6, 7, 8 and 10 inches square, about 11 feet long, and weigh from 1,300 to 3,750 pounds, depending upon the size of the round billet required for the size pipe to be made. The billets are from three to eight inches in diameter; they are cut to the proper length by a hot saw. The length of the billet depends upon the weight of the metal required for the product.

The main transformation from the billet to the tube is in the rolling. The next step is that of reeling, which produces a little further reduction and a smoothing of the surface. The final rolling is that of sizing or finishing. The rolling and reeling operations are inidcated in Figs. 6 and 7, respectively. In Fig. 8 is a typical layout of a seamless tube mill.

The cupping system for making seamless tubes is employed to a great extent for pipe larger than nine inches diameter. The first patent on this system is dated 1851. The steel used is plate of about

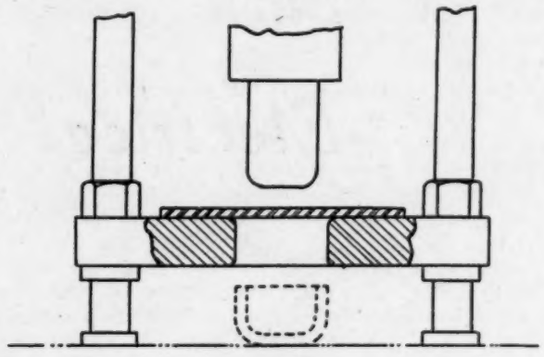


FIG. 9.

the same chemical content as a billet intended for pipe manufacture. The plate is either hot sheared or punched into a disc, or for very large pipe turned in a large boring mill. The size of the plate depends upon the volume of metal required for the pipe. It may be from three-eighths to four inches thick and from two to seven feet across.

The first forming operations are made in a vertical punch press. This is a heavy machine with a horizontal recess in the bench frame, through which passes a hydraulically operated plunger. The cup is formed from the disc, as indicated in Fig. 9, and deeper cups of smaller diameters are produced, in turn, by changing the dies and punches on the end

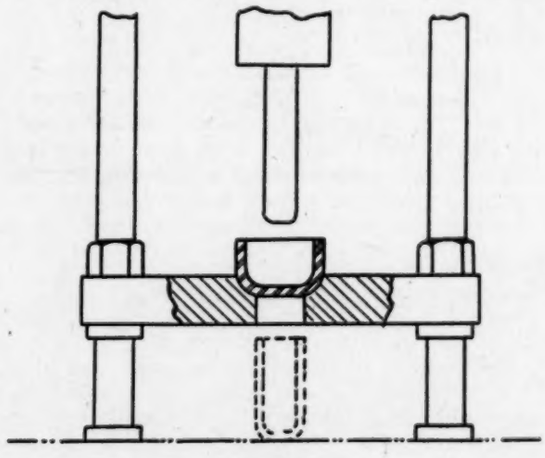


FIG. 10.

of the plunger. See Fig. 10. These changes are made very quickly and with relative ease. The number of punches with one heating of the metal depends upon the temperature requirements, therefore, a cup may be heated as many as twelve times before it is a finished tube. The last hot drawing operations may be done on a horizontal draw bench by forcing the material, which is now of tube shape

with one closed end, through a series of dies, as shown in Fig. 11. Later the closed end is cut off and the tube straightened.

When it is desired the hot rolled tubes may be cold drawn in the finishing operations. This is done in chain bench, at one end of which is fixed a die

FIG. 11.

through which the metal is drawn by heavy tongs which are hooked onto the chain. So that the metal may be pushed through the die and to permit the jaws to get a good grip on it, the piece must first be pointed in a small punch press which reduces the diameter of the metal by crushing it into an almost solid mass for a short distance from the end. A general idea of the cold drawing arrangement may be obtained from Fig. 12. Cold drawing makes the tube hard and brittle and therefor, before another drawing can be made, it must be annealed. Reheating the tube causes black oxide to form scale on the surfaces. This scale must be removed before the next operation by means of pickling in an acid bath which is kept in motion by jets of steam. After the drawing process is completed the tube is straightened by one of three or four types of machines. The straightener may be a simple gag press,

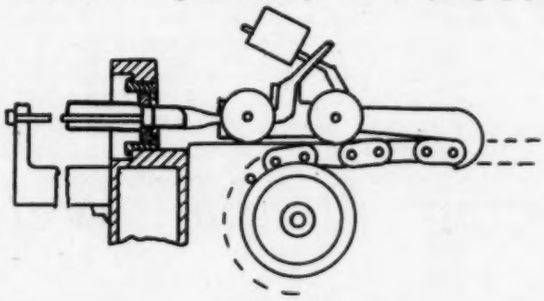


FIG. 12.

which requires a very skilled operator, or it may be a double series of rolls alternately above and below the tube, or it may be two very long rolls with their axes almost parallel with the pipe and so grooved as to fit the pipe for their entire length. The latter type is indicated in the layout in Fig. 1. After cooling the pipe is machine cut into desired lengths.

The following information on chemical content, tensile and physical properties of steel tubing may be of general interest:

Carbon	Man.	Ph.	Sul.	Ni.	Chr.	Yield Pt. # /sq. in.	Min. Ten. Strength	Elon- gation 2"	Elon- gation 8"	Red.of Area Pct
10-15	30-60	040	045	....	....	27000	47000	50	27	50
						28000	50000	52	28	52
15-20	30-60	040	050	....	....	45000	58000	17	10	30
						38000	52000	32	15	35
						35000	50000	45	22	45
						55000	63000	10	3	18
20-30	35-65	040	050	....	....					
30-40	35-65	040	050	....	....	65000	80000	18	10	20
						48000	65000	32	18	32
						70000	85000	10	....	12
40-55	35-65	040	050	....	....					
20-30	35-65	040	050	3-3.75						
15-25	40-70	040	050	1.15	40-70					

The sizes and types of motors required for a tube mill depend upon the size and type of mill and so many other items that each drive in the mill must be determined individually. To give a general idea of what the requirements may be the following tables are presented:

MAIN AUXILIARY EQUIPMENT

Lap Weld Mill—6 In. by 16 In.

Motor Drive	No.	Hp.	Type	Speed	Reversible
Scarfing Machine	1	50	AC	700	No
Scarfing Machine	1	10	DC	750	No
Scarfing Table	1	10	AC	700	No
Bar Puller	1	15	AC	700	No
Straightening Press	1	15	AC	700	
6 in. to 16 in. Threader	8	10	DC	400/1600	No
Coupl. Screwing Mach.	2	10	DC	400/1600	No
Hot Bed Table	1	10	DC	400/1600	No
Cross Roll Machine	2	25	DC	400/1600	Yes
Welding Fce. Charger	1	15	DC	700	Yes
Welding Fce. Charger	1	10	DC	750	Yes
Bending Rolls	1	50	DC	750	No
Bending Rolls	1	10	DC	500	No
Shear	1	30	AC	850	No
Bending Bench	1	50	DC	500/750	No
Butt Weld Mill					
Cross Roll	2	7½	DC	650/1300	No
Clipping Shear	1	7½	AC	870	No
Draw Bench	1	50	DC	650/1130	No
Draw Bench	1	5½	DC	760	Yes
Hot Bed Tables	1	7½	DC	650/1300	No
Hot Saw	2	15	AC	1750	No
Rotary Cutter	1	10	AC	870	No
Threader	10	5	DC	400/1200	Yes
Coupling Screw Mach.	2	7½	DC	650/100	Yes
Ventilating Fans	1	25	DC	800	No
Seamless Tube Mill					
Hot Bed	1	10	AC	590	No
Threader	10	5	DC	400/1200	No
Tables	6		DC		Yes
Conveyor	2		DC		
Press Straightener	1	40	AC	590	No
Press Straightener	1	15	AC	870	No
Clipping Shear	2	7½	AC	870	No

MAIN DRIVES—SEAMLESS TUBE MILLS

Piercing Mills

Motor	Mill A	Mill B
Hp.	1800/1350	750/550
Volts	2200	2200
R.P.M.	252	353
Cycles	60	60
Type	Wound Rotor Induct.	Wound Rotor Induct.
Gear Unit		
Hp.	1800	750
Reduction	257 to 85	360 to 96
Starting Torque Pound-feet	7500	2200
Typical Product		
Size Billet	9 in. dia. x 5 ft.	3 in. dia. x 40.5 in.
Size Finished	9½ in. O.D. x 0.633 in.	2.45 in. O.D. x 0.140 in.
Size from Mill	10 in. O.D. x 0.813 in.	3 7/16 in. x ¼ in.
Size Plug	7¾ in.	2¼ in.
Pounds	1100	80
Pieces per Hr.	38	218
Average Hp.	985	128
Kw-Hr. per Ton	39	12.5
Speed thru mill	24 ft. per min.	98 ft. per Min
Size Billet	4½ in. dia. x 4 ft.	
Size Finished	5½ in. O.D. x 0.153 in.	
Size from Mill	5¼ in. O.D. x 5/16 in.	
Size Plug.	4⅛ in.	
Pounds	215	
Pieces per Hr.	87	
Average Hp.	450	
Kw-Hr. per Ton	40	
Speed thru Mill	55.5 ft. per min.	

	Rolling Mills	
Motor	Mill C	Mill D
Hp.	1200/900	750/550
Volts	2200	2200
R.P.M.	294	353
Cycles	60	60
Type	Wound Rotor Induct.	Wound Rotor Induct.
Flywheels		
Number	2	2
Hp.—Sec.	13,200	10,700
Size Billet	4½ in. dia. x 4 ft.	3 in. dia. x 40.5 in.
Size Finished	5½ in. O.D. x 0.153 in.	2.45 in. O.D. x 0.140 in.
Size from Mill	5⅛ in. O.D. x 0.160 in.	3⅜ in. O.D. x 0.120 in.
Size to Mill	5¼ in. O.D. x ⅞ in.	3⅞ in. O.D. x ¼ in.
Pounds	215	80
Pieces per Hr.	174	184
Average Hp.	50	114
Kw-Hr. per Ton	2.22	12.7
Speed Thru Mill	6.1 ft. per sec.	
No. of Passes	2	2
	Reeling Mill	**Sinking Mill**
Motor	Mill E	Mill F
Hp.	150	250
Volts	2200	2200
R.P.M.	375	350
Cycles	60	60
Type	Wound Rotor Induct.	Wound Motor Induct.
Typical Product		
Billet	3 in.. dia. x 40.5 in.	3 in. dia. x 30 in.
Size Finished	2.45 in. O.D. x 0.140 in.	2.45 in. O.D. x 0.140 in.
Size to Mill	3⅛ in. O.D. x 0.120 in.	3½ in. O.D. x 0.13 in.
Size from Mill	3½ in. O.D. x 0.130 in.	2.45 in. O.D. x 0.140 in.
Pounds	80	60
Pieces per Hr.	114	179
Average Hp.	53	85
Kw.-Hr. per Ton	10	13
Speed Thru Mill	59.5 ft. per min.	240 ft. per min.

To indicate the range and distribution of motors on main roll drives of tube mills the following list is given:

Type of Mill	H.P.	R.P.M.	Volts	Cyc.	Drive	User
Pipe Mill	150	590	220	D.C.	Direct	National Tube Co.
Tube Mill	220	600	2200	60	Gear	N. J. Tube Co.
Tube Roll	300	345/500	500	D.C.	Gear	Pgh. Steel Prod. Co.
Tube Mill	300	514	440	60	Gear	Detroit Seamless
Pierce Mill	300	500	230	D.C.	Gear	Langers Villa, Fr.
Seamless	300	350	2200	60	Gear	Timken Roller Brg.
Tube Mill	300	514	220	60	Gear	Detroit Seamless
Tube Roll	300	500	550	25	Gear	Baltimore Tube Co.
Tube Mill	300	600	2200	60	Gear	Weldless Tube Co.
Pipe Weld	250	435	2200	60	Gear	Steel & Tube Co.
Weld. Rolls	350	350/450	230	D.C.	Direct	National Tube Co
Pipe Mill	400	435	400	60	Gear	Steel & Tube Co.
Weld. Rolls	400	375	220	25	Gear	Yngsto'n-S. & T. Co.
Tube Mill	400	600	440	60	Gear	Globe Seamless Tube
Brass Tube	400	514	2200	60	Gear	American Brass Co.
Pierce Mill	400	600	440	60	Gear	Chase Metal Works
Tube Roll	500	500	550	25	Gear	Baltimore Tube Co.
Tube Mill	500	350	2200	60	Gear	American Brass Co.
Tube Mill	500	450	2200	60	Gear	Ohio Seamless Tube
Pierce Mill	500	360	2200	60	Gear	Weldless Tube Co.
Pierce Mill	600	485	550	25	Gear	Baltimore Tube Co.
Tube Mill	600	360	2200	60	Gear	Standard Seamless
Pierce Mill	700	150	2200	60	Rope	Ohio Seamless Tube
Tube Roll	750	353	2200	60	Direct	National Tube Co.
Pierce Mill	750	353	2200	60	Direct	National Tube Co.
Pierce Mill	750	235/325	230	D.C.	Direct	Pgh Seamless Tube
Pierce Mill	800	200/300	500	D.C.	Rope	Pgh. Steel Prod. Co.
Pierce Mill	800	257	2200	60	Direct	Std. Seamless Tube
Pierce Mill	800	250	2200	60	Gear	Timken Roller Brg.
Tube Mill	1000	240	220	60	Gear	Globe Seamless Tube
Pierce Mill	1000	450	2200	60	Gear	Winches'r Rep. Arms
Tube Roll	1200	294	2200	60	Gear	National Tube Co.
Tube Roll	1200	257	4600	60	Rope	Detroit Seamless
Tube Roll	1200	250	2200	60	Direct	Takata & Co.
Tube Roll	1800	250	2200	60	Direct	National Tube Co.

Two Methods of Producing Ductile Welds

TWO methods for producing ductile welds have been developed by research scientists of the General Electric Company, working in different laboratories hundreds of miles apart. Both of the methods, similar in some respects, mark a decided step in the utilization of the heat of electric arcs in the joining of metal parts or the building of metal structures. The one was developed in the Schenectady research laboratory by Dr. Irving Langmuir; the other was developed in the Thomson research laboratory at Lynn, Mass., by Peter Alexander.

In both processes, air is excluded from the metal by means of a bath of hydrogen or other gas. The formation of oxides and nitrides in the weld metal is thus prevented, and the fused metal is as strong and ductile as the original metal.

In brief, the method developed by Dr. Langmuir in Schenectady is to pass a stream of hydrogen between two electrodes. The heat of the arc breaks up the hydrogen molecules into atoms. These combine again a short distance in front of the arc into molecules of the gas, and in so doing liberate an enormous amount of heat, so that much higher temperatures can be obtained with this than with the usual welding methods. Since atomic hydrogen is a powerful reducing agent, it reduces any oxides which might otherwise form on the surface of the metal Alloys containing chromium, aluminum, silicon or manganese can thus be welded without fluxes and without surface oxidation.

The process developed in the Lynn laboratory by Mr. Alexander is based on the utilization of the chemical and physical properties of hydrogen and other gases in their molecular state. This process aims primarily at the prevention of the formation of the nitrades and oxides in the arc-deposited metal, which limit the ductility of the usual arc welds.

In this process the arc is struck between the metallic wire or carbon used, as one electrode and the plate or work to be welded used as another electrode. The crater of the arc is always on the work to be welded. The gaseous atmosphere is supplied in a form of a stream around the arc. Pure hydrogen, water gas, hydrogen-nitrogen mixtures, anhydrous ammonia, methanol vapor and some other suitable gases can be used, according to the nature of the work. The hydrogen-carbon monoxide mixtures were suggested by Prof. Elihu Thomson; water gas and methanol are examples of such mixtures.

This process makes the arc welding process more efficient and suitable for the fields which at present are out of its reach. Low carbon steel, alloy steels, and most of the non-ferrous metals and alloys can be welded with success by this process in suitable gaseous mixtures.

Atomic Hydrogen Arc Welding

Fifteen years ago, while studying the loss of heat of the tungsten filaments of incandescent lamps in an atmosphere of hydrogen gas, Dr. Irving Langmuir of the General Electric research laboratory at Schenectady found that at a high temperature the hydrogen gas changed from the molecular to the atomic state. In the molecular state, two atoms of the gas are grouped together as a unit; in the atomic state each atom acts as a unit. The molecular form is the more stable, and when the atoms recombine to form the molecules intense heat is liberated.

Dr. Langmuir's study of the filaments in hydrogen was a theoretical investigation. Now, fifteen years later, the results have been applied in a different field—in the development of a new method of welding, by which it is possible to produce welds as strong and as ductile as the original materials.

Continuing the theoretical investigation, Dr. Langmuir found that more atomic hydrogen was formed by passing powerful electric arcs between tungsten electrodes at atmospheric pressure. By directing a jet of hydrogen from a small tube into the arc, the atomic hydrogen could be blown out of the arc, forming an intensely hot flame of atomic hydrogen burning to the molecular form and liberating about half again as much heat as does the oxy-hydrogen flame. In this flame molybdenum, one of the most refractory of metals, melts with ease; quartz, however, melts less easily, in spite of its lower melting point. This indicates that the metal assists in the action as a catalyzer—which scientists define as a substance which accelerates a chemical change.

By this method, iron can be welded or melted without contamination by carbon, oxygen or nitrogen. Because of the powerful reducing action of the atomic hydrogen, alloys containing chromium, aluminum, silicon or manganese can be welded without fluxes and without oxidation. The rapidity with which such metals as iron can be melted seems to exceed that in the oxy-acetylene flame, so that the process promises to be particularly valuable for welding.

The technical development of this welding process has been the work of several men in the Schenectady laboratory, including R. A. Weinman and Robert Palmer. These men have developed and tried many types of welding torches, and have tried them under varying conditions. At the same time tests of numerous types of welds have been conducted.

The two electrodes of the torch are tungsten rods, held at an acute angle with each other by lava insulators. When not in use, the electrodes are in contact with each other; they can be separated by pressure on a lever mounted on the handle. A set screw is provided for making slow adjustments of the electrodes. The hydrogen is supplied by a tube through the handle. Sufficient gas is used so that not only are the electrode tips surrounded by enough to form the blast of atomic hydrogen, but by an additional quantity to surround the work with hydrogen.

Either alternating or direct current can be used. The first mentioned has been found more convenient, and electrodes of smaller diameter can be used. The gas pressure required to operate the torch is very small; in the laboratory, with short lengths of tubing, a pressure of less than one pound per square inch was sufficient with metals up to one-half inch in thickness. For ordinary welding, the rate of gas consumption varies between 20 and 30 cubic feet per hour.

Since the maximum rate of heating is desired in welding, the torch is held close to the metal. Best results have also been obtained when the torch is inclined, so that the blast of hydrogen from the torch passes over the pool of molten metal in a direction opposite to that in which the torch is moved along the line of the weld.

Experiments have been conducted with several gas mixtures and various electrode materials. The best results have usually been obtained with tungsten electrodes and hydrogen alone.

Materials of many kinds have been successfully welded by this method. Low carbon steels up to one-half inch in thickness have been welded without additional material after butting together tightly. Considerable work has also been done in connection with full automatic welding using a butt joint, and with no metal being added to the seam. A number of welds have been made on seamless tubing having a wall thickness of one-quarter inch and an outside diameter of four inches, and with boiler plate iron one inch thick. Welds on deoxidized copper such as silicon-copper have been made up to three-eighths inch thick metal, giving unusually good sections.

In testing welds made by this process, the welded portions have been twisted and bent double without cracking or otherwise being injured. Such a procedure has not been possible with the ordinary arc weld, since such welds are usually brittle because of the presence of nitrides or a thin film of oxide or scale, removed in the new process by the presence of hydrogen.

Electric Arc Welding in Gaseous Atmosphere

By surrounding the ordinary welding electrodes with an atmosphere of hydrogen or certain other gases, it has been found by Peter Alexander, of the Thomson Research Laboratory of the General Electric Company at Lynn, Mass., that it is possible to produce ductile welds. The gas acts as a flux and shield against the oxygen and nitrogen of the air; therefore, the formation of oxides and nitrides of iron in the molten metal is prevented. The process originated from the study of metallurgy of the arc-deposited metal and the causes that limit its ductility.

The method is based on the action of molecular hydrogen. This gas, at high temperatures, even in the molecular state, is a very active reducing agent. When it surrounds the crater of the arc it acts in the same way as it does in the hydrogen brazing process. Yet certain peculiarities of the process (for example, the extremely high voltage drop at cathode and anode of the arc burning in hydrogen) are due to the dissociation of the small amounts of molecular hydrogen in actual contact with the craters. Hence the apparent resistance of the arc, and consequently the amount of energy liberated, is about double that when the arc is burning in air.

Consequently the weld is not only ductile, but the operation is much faster. The speed results both from the greater energy of the arc in the hydrogen atmosphere and the fact that beveling of the edges of the material is unnecessary. Using 180 amperes and an arc voltage of 60, one-quarter inch boiler

plates, butted together without beveling, have been welded at a speed of 60 feet per hour.

Ductility is a factor of prime importance in the welds of structures that are subjected to vibration, accidental bending stress or overload. Also, ductility equalizes internal cooling stresses when present in the weld. If any part of the ductile weld is stressed beyond its elastic limit, it will not crack. It will yield until the stresses are more or less equalized all along the joint, which is so proportioned as to stand with safety the imposed load. It has also been found that the metal deposited in the hydrogen atmosphere has a higher elastic limit. The elastic limit of pure iron electrodes before deposition averages 29,000 pounds per square inch; the elastic limit of the same electrode deposited by the arc in hydrogen averages 42,000 pounds per square inch.

In this welding process the arc is maintained inside of a hydrogen stream which burns along its outer surface of contact with air. The electrode is entirely surrounded by hydrogen, which eliminates the possibility of the metal in the crater coming in contact with air. Direct current is used. The equipment as developed in the laboratory includes the direct-current generator, gas hose and spool of welding wire mounted as a unit on one base. The welding wire, the hydrogen gas and the electric current are sent through a flexible hose to the torch nozzle.

After the work with the hydrogen atmosphere was found to be successful, experiments with mixtures of hydrogen and carbon monoxide were conducted in accordance with Prof. Elihu Thomson's suggestion, and under his personal guidance. Water gas, containing about equal volumes of hydrogen and carbon monoxide, was next tried. It was found that welds produced in such an atmosphere were ductile and easier to produce. Work with various mixtures of carbon monoxide and hydrogen, produced either synthetically or by decomposition of various organic compounds, demonstrated that ductile welds can be produced in the atmosphere of any mixture of the two gases. Methanol or synthetic wood alcohol was found to serve well in this gas, so that transportation with portable outfits is facilitated.

A series of experiments with nitrogen-hydrogen mixtures showed that mixtures of these gases also give ductile welds. The use of liquid anhydrous ammonia which contains one volume of nitrogen and three of hydrogen, in this connection makes it possible to store large quantities of the gas in small volume as a liquid.

Still other gases and methods are being investigated in the Lynn laboratory, and academic studies are being made of the theoretical aspect of welding in different gases.

In its present state the process is being extended to the welding of alloy steels, non-ferrous materials and their alloys. The careful selection of the appropriate gaseous mixture determined by the nature of the materials to be welded is an essential factor for successful work.

In brief, this process is a combination of an electric arc which supplies the energy and an appropriate chemical reagent which, being in a gaseous state and at extremely high temperature, acts almost instantaneously.

Items of Interest

The efficiency of the oil-electric locomotive—the most recent development in the motive power field, but now an assured success after years of experimentation—was strikingly demonstrated in a series of tests made made by the Central Railroad of New Jersey during December.

At the Bronx Terminal in New York City a sixty-ton oil-electric, operating for 24 days during December, in 347 hours of locomotive service, handled a total tonnage of 61,556 at a total fuel cost of $72.58. A steam locomotive, operating under almost identical conditions in December, 1924, in 24 days rendered 297 hours service, and during this time moved a tonnage of 50,493 at a cost for fuel and oil of $349.46.

The oil-electric, in other words, handled 11,000 more tons than the steam locomotive and at a fuel cost of approximately 20 per cent, as compared with the steam engine.

The cost of fuel per 1,000 tons handled was $1.16 for the oil-electric as compared with $6.92 for the steam locomotive.

The saving in fuel costs is only one of the many economies made possible by the oil-electric. It will make possible elimination of coaling plants, ash pits, turn tables and expensive round houses and hostling services. Very little water is necessary, thus eliminating costly watering stations and troubles due to bad water conditions.

Use of the oil-electric locomotive would reduce locomotive maintenance costs by one-half; and each oil-electric, during the course of a year, would be able to render twice as many hours of service as are now obtainable from the steam locomotive.

The following statistics, as compiled by the Central Railroad of New Jersey, afford the first real comparison of the relative efficiency and operating costs of the oil-electric and a steam locomotive.

Central Railroad of New Jersey—Bronx Terminal, N. Y. Comparative Operation—60 Ton Oil-Electric vs. Steam—Month of December, 1924, 1925

	Oil-Electric 1925	Steam 1924
Number of days	24	24
Hours of locomotive service	347	297
Operating fuel consuming hours	318	297
Fuel oil used, gallons	1038	
Diesel lubricating oil used, gallons	25	
Gasoline used	5	
Engine oil used	5	5
Valve oil used	10	5
Star cup grease used, lbs.	1	
Kilowatt hours generated	6614	
Coal Used tons	0	41

Number of floats handled—		
In	57	47
Out	57	46
Total	114	93
Number of cars handled—		
In	947	775
Out	943	765
Total	1890	1531
Tons handled—		
Off float (net 19908)	38889	31040
On float (net 3766)	22667	19453
Total (net 23674)	61556	50493
Includes tar weight of cars.		
Cost of operation:		
Fuel oil at $.05 per gal.	$51.90	
Diesel engine lub. oil, $.53 per gal.	13.25	
Gasoline at $.145	.72	
Water at $.01/10 cu. ft.	.03	$28.37
Engine oil at $.262 per gal.	1.31	1.31
Valve oil at $.53 per gal.	5.30	2.65
Star cup grease at $.07 per lb.	.07	
Coal cost at $7.15 per ton		293.15
Coal cost handling		24.00
Total cost of fuel, coal, oil, etc.	$72.58	$349.46
Daily Operating Average		
Hours of locomotive service	14.5	12.4
Operating fuel consuming hours	13.3	12.4
Fuel oil used, gallons	43.2	
Diesel lub. oil used, gallons	1.04	
Gasoline	Neg.	
Coal used, tons		1.7
Kilowatt hours generated	275	
Number of floats handled	4.75	3.87
Number of cars handled	79	64
Number of tons handled	2565	2104
Cost of fuel, oil, coal, etc., total	$2.98	$14.56
Cost of fuel, oil, coal per 1000 tons handled	1.16	6.92
Operating Hourly Average Cost		
Fuel, oil, coal, water, etc.	$.228	$1.18
Per car on and off floats	.038	.228
Per ton on and off floats	.0011	.0069
Cost per KW hour	.0109	
No. tons handled per hour	193	170
Rate BHP hours per gal. lub. oil	3820	
Lbs. fuel oil per KW hour generated	1.13	
Oil engine load factor	9.62%	

Great strides were made in the improvement of power panel design, during the year just passed.

Square D engineers, in touch with industrial engineers, learned that what plant electricians wanted was more flexibility and lower panel maintenance costs.

In building a power panel which would provide both these characteristics, Square D engineers took advantage of the individual base construction which had proven so satisfactory in safety switch construction.

The Square D Convertible Power Panel, which was announced to the trade during the year, provides a simple and easy means of adjustment, which makes it posisble to use either 30, 60 or 100 ampere fuses in any of the circuits. This construction provides the flexibility which the plant engineers were so anxious to obtain.

In the convertible power panel, each fuse jaw, connector and solder lug are mounted on individual insulating bases. These bases are held in place by metal strips. Merely loosening several nuts it is possible to move the position of the base and to provide the proper spacing for either 30, 60 or 100 ampere fuses.

In providing for lower maintenance costs, again the individual base construction provided the answer. In the old type panel it was a big job to change a fuse clip. The base had to be removed from the cabinet, the wires had all to be disconnected, the heavy trims lifted off. In the convertible panel, a fuse clip can be removed from the front of the panel without disconnecting all the wires or removing the base from the cabinet. Removing a single screw from the front of the panel is all that is necessary to remove the fuse clip.

To further provide for low cost maintenance, a quick and easy access to the gutters has been provided. The top, bottom and side trims of the convertible power panel are all hinged separately. It is not necessary to remove any of these trims and by merely removing a few bolts, one man can get easy access to the gutter wiring.

The panel construction is also such that the 440 and 600 volt panels can be used for 220 volts if desired.

200 ampere circuits and over can be provided when specified on special order, but these circuits are not convertible.

Motor Starters for Use With Protective Cutouts

The Square D line of motor-starting switches was augmented during the year by the addition of motor starters for use with time limit protective cutouts. These switches are available for use on 125-250 volts and for 500-600 volts AC.

The approval of plant engineers, during the year past, and those preceding, have committed the Square D Company to a continuance of their policy of supplying equipment which gets its reputation from performance and not from a price tag.

The Square D Company, through their sales manager, A. A. Schueler, announce the appointment of several new salesmen and the promotion of others.

G. E. Daub has become a member of the sales force in the Atlanta territory with headquarters at Birmingham, Ala.

Roy L. McCreary is now a salesman in the Cleveland territory, with headquarters at 715 Hippodrome Bldg., Cleveland, Ohio.

J. F. O'Hara, who was with the company several years ago, has returned, this time as a salesman in the Detroit territory.

Jack Kingsley has been appointed branch sales manager of the Springfield (Mass) territory.

C. L. Hull has been appointed Eastern District sales manager, with supervision over the Baltimore, Philadelphia, New York, Springfield, Boston and Syracuse territories.

The Clark Controller Company of Cleveland, Ohio, has appointed Mr. A. B. Holcomb, District Manager, in charge of their Pittsburgh office, 994 Union Trust Building.

The Cutler-Hammer Mfg. Co., of Milwaukee, Wis., has opened a new sales office in the Healey Building, Atlanta, Georgia. This office will take care of the trade in the states of North Carolina, South Carolina, the eastern section of Tennessee, Georgia, Florida, Southern Alabama and Mississippi

ADVERTISING PAGES REMOVED

Mr. A. C. Gibson, formerly of the Philadelphia office, is in charge.

An item of considerable interest to many electrical men is the association of Henry H. Mulier Co., as Pittsburgh Agents of the Packard Electric Company. Mr. Henry H. Muller, head of the company which bears his name, has associated with him Mr. H. E. Ransford, who is well known in Pittsburgh electrical circles. Mr. Muller himself is probably one of the best-known men in the electrical fraternity of the Smoky City. As sales engineers, Mr. Muller and Mr. Ransford have a background of many years of broad experience in design, construction and operation of central station and industrial transmission and distribution systems. In order that their experience and knowledge will be utilized by the buyers in the Pittsburgh territory to the greatest advantage they are specializing on electric transmission equipment.

Allis-Chalmers business in Continental Europe will be handled through an organization recently incorporated as Allis-Chalmers (France), with headquarters at 3 rue Taitbout, Paris. Mr. H. I. Keen, who has been manager of European sales through the company's district office in Paris, will be the managing director of the new organization.

The company has maintained for many years an office in London, 728 Salisbury House, London Wall, F. C. 2.

Coincident with the organization of the Graybar Electric Company, formerly the Supply Department of the Western Electric Company, announcement is made of the promotion of Leo M. Dunn, to the vice presidency of the new company. Mr. Dunn will have charge of merchandizing and accounting.

Mr. Dunn went to work in March, 1886, with the Central District Printing & Telegraph Company of Pittsburgh, an operating telephone concern associated with the Western Electric Company. At the time Mr. Dunn was an 11-year-old office boy. There were only ten employes in the general offices of the company in that year, and not a great number in the entire organization.

Stepping into his first supervisory job at the age of nineteen, Mr. Dunn started on a long and conspicuous career in the supply distributing business of the Western Electric Company. He held, successively, a number of important positions. In 1910 he was chief storekeeper of the Pittsburgh distributing house. He became manager at Pittsburgh in 1913, and manager of the Philadelphia house in 1918; the next year he was made assistant Eastern district manager. Two years later he was transferred to New York as manager of the New York distributing house and Eastern district manager. He became general merchandize manager of the supply department in 1923, a position which he has held up to his present advancement to the vice presidency of the Graybar Electric Company.

Henry Disston & Sons, Inc., of Philadelphia, announce the appointment of Mr. E. A. C. Baum as assistant Western representative for steel sales, with headquarters at the Disston Chicago branch, 111 North Jefferson street.

Mr. Baum formerly was metallurgical engineer with the Illinois Tool Co., and comes into the sales field after many years of experience in the handling and use of tools and tool steels.

The Monitor Controller Company of Baltimore, Md., manufacturers of Automatic Controllers for all kinds of motor-driven apparatus, Thermaload Across-the-Line Starters and Edgewound Resistors, announce the establishment of Pacific coast representative with Electric Material Company of San Francisco and Los Angeles.

The Electric Material Company are particularly well known on the Pacific coast, having been established for a number of years as representatives of a number of electrical manufacturers such as Ward Leonard Electric Company, Roller Smith Company, G & W Electric Specialty Company and Autovent Fan & Blower Company.

It is proposed to eventually have some stock of standard equipment carried in San Francisco.

STANDARDIZED MILL TYPE MOTOR

(Continued from page 111)

The question was then brought up as to whether any change should be made in the line of ratings and speeds for the proposed line of motors. The Committee submitted to the manufacturers the list of ratings which they compiled from a study of the replies to the questionnaire forwarded to the membership of the Association.

It was then found feasible to reduce the total number of frame sizes required to eight, as compared to the present eleven frame sizes now being manufactured.

The next question discussed was that of selecting proper speeds. The replies to the questionnaire indicated that the active membership of the Association were averse to increasing the speeds in mill type motors and the point of low speed was very strongly emphasized as essential to simplifying the machinery they construct.

There was also a discussion of the advisability of designing the proposed line of motors so that they would accommodate both roller and sleeve bearings. The replies to the questionnaire indicated that those answering who had extensive experience with bearings felt the development of the anti-friction bearing had progressed to the point where they should be considered entirely satisfactory for steel mill service and that, therefore, roller bearings only were required. On the other hand, the majority of replies, based on numbers, would indicate that motors equipped with both types of bearings would be in demand.

The manufacturers were asked to submit their views on the subject with the idea of determining whether designing motors to accommodate both types of bearings was a serious handicap.

The short write-up above is not to be considered in any way as a complete report of the transactions of the meeting of March 12, but is simply written with a view of keeping the engineers of the steel industry acquainted with just how far this matter has progressed with the committee appointed.

Due to the great amount of detail work involved, it will not be possible to include a final report in this issue, but it is hoped that the committee will have advanced sufficiently far by the time the next issue is printed to have incorporated therein the complete details of the meeting with the manufacturers.